RICS PROFESSIONAL STANDARD

Whole life carbon assessment for the built environment

Global

2nd edition, September 2023

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Effective from 1 July 2024

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Contents

RICS standards framework

RICS’ standards setting is governed and overseen by the Standards and Regulation Board (SRB). The SRB’s aims are to operate in the public interest, and to develop the technical and ethical competence of the profession and its ability to deliver ethical practice to high standards globally.

The RICS Rules of Conduct set high-level professional requirements for the global chartered surveying profession. These are supported by more detailed standards and information relating to professional conduct and technical competency.

The SRB focuses on the conduct and competence of RICS members, to set standards that are proportionate, in the public interest and based on risk. Its approach is to foster a supportive atmosphere that encourages a strong, diverse, inclusive, effective and sustainable surveying profession.

As well as developing its own standards, RICS works collaboratively with other bodies at a national and international level to develop documents relevant to professional practice, such as cross-sector guidance, codes and standards. The application of these collaborative documents by RICS members will be defined either within the document itself or in associated RICS-published documents.

Document definitions

Document type	Definition
RICS professional standards	**Set requirements or expectations for RICS members and regulated firms about how they provide services or the outcomes of their actions.** RICS professional standards are principles-based and focused on outcomes and good practice. Any requirements included set a baseline expectation for competent delivery or ethical behaviour. They include practices and behaviours intended to protect clients and other stakeholders, as well as ensuring their reasonable expectations of ethics, integrity, technical competence and diligence are met. Members must comply with an RICS professional standard. They may include: • mandatory requirements, which use the word 'must' and must be complied with, and/or • recommended best practice, which uses the word 'should'. It is recognised that there may be acceptable alternatives to best practice that achieve the same or a better outcome. In regulatory or disciplinary proceedings, RICS will take into account relevant professional standards when deciding whether an RICS member or regulated firm acted appropriately and with reasonable competence. It is also likely that during any legal proceedings a judge, adjudicator or equivalent will take RICS professional standards into account.
RICS practice information	**Information to support the practice, knowledge and performance of RICS members and regulated firms, and the demand for professional services.** Practice information includes definitions, processes, toolkits, checklists, insights, research and technical information or advice. It also includes documents that aim to provide common benchmarks or approaches across a sector to help build efficient and consistent practice. This information is not mandatory and does not set requirements for RICS members or make explicit recommendations.

Glossary

Term	Definition
Biogenic carbon	Carbon removals associated with carbon sequestration into biomass, as well as any emissions associated with this sequestered carbon. Biogenic carbon must be reported separately if reporting only upfront carbon, but should be included in the total if reporting embodied carbon or whole life carbon.
Bioenergy with carbon capture and storage (BECCS)	The capture and permanent storage of carbon dioxide (CO_2) from processes where biomass is converted into fuels or directly burned to generate energy (source: International Energy Agency).
Biomass	Material of biological origin, excluding material embedded in geological and/or fossilised formations.
Building information modelling (BIM)	A digital representation of physical and functional characteristics of an asset, creating a shared knowledge resource for information about it and forming a reliable basis for decisions during its life cycle, from earliest conception to end of life.
Carbon capture, utilisation and storage (CCUS)	The capture of CO_2, generally from large point sources like power generation or industrial facilities that use either fossil fuels or biomass as fuel (source: International Energy Agency).
Carbon dioxide equivalent (CO_2e)	A metric for expressing the impact of all greenhouse gases on a carbon dioxide basis.
Carbon removal	The process by which CO_2 is removed from the atmosphere and stored, for example by using: • nature-based solutions such as restoring forests and soils, and innovative farming practices • technology, such as bioenergy with carbon capture and storage (BECCS), or direct air carbon capture and storage, and • long-lasting products and materials, such as wood-based construction (source: European Commission).

Term	Definition
Carbon Risk Real Estate Monitor (CRREM)	Provides the real estate industry with transparent, science-based decarbonisation pathways aligned with the Paris Climate Goals of limiting global temperature rise to 2°C, with ambition towards 1.5°C. These pathways enable industry stakeholders to estimate carbon and stranding risks associated with premature obsolescence.
Carbon sequestration	The process by which CO_2 is removed from the atmosphere and stored within a material, for example by being stored in biomass as biogenic carbon by plants.
Category	A division of project or sub-project costs and/or carbon emissions into acquisition, construction, renewal, maintenance, operation, and end of life.
Category A (Cat A) fit-out	A Category A fit-out includes basic finishes to the floors, walls and ceilings: the space is finished but with no fixtures and fittings such as partitions, meeting rooms or individual offices laid out. The office space will be functional but not include the final specifications included in a Category B fit-out.
Category B (Cat B) fit-out	A Category B fit-out follows on from a Category A fit-out and typically includes bespoke partitioning, finishes, carpeting, lighting, kitchen facilities, etc. that are specific to the requirements of the occupier.
CEN c-PCR	Complementary Product Category Rules to EN 15804, developed by CEN Product Committees to cover product groups such as glass, ceramic, concrete and timber. They provide detailed guidance and requirements on the use of EN 15804 for the relevant product group.
Circular economy	An economy that is restorative and regenerative by design, and that aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.
Circularity	A process that considers the potential for recovery, reuse and recycling of items following circular economy principles.
Element	A major part of a group element (e.g. the elements that comprise group element 3: Internal finishes are 3.1: Wall finishes, 3.2: Floor finishes and 3.3: Ceiling finishes). A separate cost target can be established for each element. Note also the use of the term 'cost group' or 'cost sub-group' in the context of ICMS.

Term	Definition
Elemental breakdown	See *Element category*.
Element category	A division of a project or asset under which elements can be grouped. In NRM and ICMS, this is also called a group. The resulting structure with grouped elements is called an elemental breakdown.
End-of-waste state	The point when waste has been recovered so: • it is commonly used for specific purposes • a market or demand exists for it • it fulfils technical requirements and meets the existing legislation and standards applicable to products, or • its use will not lead to overall adverse environmental or human health impacts.
Environmental product declaration (EPD)	A document that clearly shows the environmental performance or impact of any product or material over its lifetime.
Global Real Estate Sustainability Benchmark (GRESB)	GRESB assessments capture information regarding environmental, social and governance performance, and sustainability best practices, for real estate and infrastructure funds, companies and assets, and are used worldwide.
Global warming potential (GWP)	A measure of how much energy (e.g. heat) the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2).
Grid decarbonisation	Gradual reduction in the energy and carbon intensity of electricity production.
Gross internal area (GIA)	Gross internal area of buildings according to RICS property measurement standards.
Group	A division of a *category* into broad groups to enable easy estimation or extraction of cost and/or carbon emissions data for quick, high-level comparison by design discipline or common purpose.
Integrated Environmental Solutions Virtual Environment (IESVE)	A suite of building performance analysis applications. It can be used by designers to test different options, identify passive solutions, compare low-carbon and renewable technologies, and draw conclusions on energy use and CO_2.

Term	Definition
Land use and land use change (LULUC)	A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use such as settlements and commercial uses, land use change, and forestry activities.
Operational carbon	The GHG emissions arising from all energy and water consumed by an asset in use, over its life cycle.
Passivhaus Planning Package (PHPP)	The building energy modelling software used to design a Passive House building.
R1 formula	Calculates the efficiency at which the energy produced from incineration and energy from waste are utilised. See the Chartered Institution of Wastes Management website for more details.
Reference study period (RSP)	Period over which the time-dependent characteristics of the object of assessment are analysed. In some cases, the RSP may differ significantly from the required service life of the construction works. Equivalent to ‘period of analysis’ used in ICMS 3.
Shell and core	Refers to the first phase of a commercial project where the basic inside (core) and the outer building envelope (shell) are constructed, without adding things like furnishings, interior lighting fixtures, interior walls or ceilings.
Sub-group	A division of a group solely according to its functions, services or common purposes to enable alternatives serving the same function to be compared, evaluated and selected.
System boundary	Defines the unit processes to be included in the assessment model. This ensures that impacts, particularly for recovery and use of recovered material, are not double counted. Based on EN 15804, it is set when the end-of-waste state is reached.

Carbon definitions for whole life carbon assessments

To be read in conjunction with Figure 2, section 2.1.

Term	Definition
Greenhouse gases (GHGs) (often referred to as 'carbon emissions' in general usage)	Constituents of the atmosphere, both natural and anthropogenic (human-created), that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds.[1]
Whole life carbon (WLC) (referred to in ICMS as 'life cycle carbon emissions' (LCCE))	Whole life carbon emissions are the sum total of all asset-related GHG emissions and removals, both operational and embodied, over the life cycle of an asset, including its disposal (modules A0–A5, B1–B7, B8 optional, C1–C4, all including biogenic carbon, with A0[2] assumed to be zero for buildings). Overall whole life carbon asset performance includes separately reporting the potential benefits or loads from future energy or material recovery, reuse, and recycling and from exported utilities (modules D1, D2).[3]
Embodied carbon or life cycle embodied carbon	The embodied carbon emissions of an asset are the total GHG emissions and removals associated with materials and construction processes, throughout the whole life cycle of an asset (modules A0–A5, B1–B5, C1–C4, with A0[2] assumed to be zero for buildings).[3]
Upfront carbon, buildings	Upfront carbon emissions are GHG emissions associated with materials and construction processes up to practical completion (modules A0–A5). Upfront carbon excludes the biogenic carbon sequestered in the installed products at practical completion.[3]
Operational carbon – energy, buildings	Operational carbon – energy (module B6) refers to GHG emissions arising from all energy consumed by an asset in use, over its life cycle.

Term	Definition
Capital carbon, infrastructure	The scope of capital carbon GHG emissions for an infrastructure asset is those that align with the scope of capital expenditure (capex), as determined by the asset owner's preference. Modules A and C must always be included within the scope, with modules B1–B5 clearly identified as 'capital' or 'operational' within the scope.
Operational carbon – infrastructure	The scope of operational carbon GHG emissions for an infrastructure asset is those that align with the scope of operational expenditure (opex), as determined by the asset owner's preference. Modules B1–B5 must each be clearly identified as 'capital carbon' or 'operational carbon' within the scope. Module B8 must be clearly identified as 'operational carbon' or 'user carbon' within the scope. Modules B6 and B7 are always 'operational carbon' within the scope.
Operational carbon – water	Operational carbon – water (module B7) refers to GHG emissions arising from water supply and wastewater treatment for an asset in use, over its life cycle.
User carbon	User carbon (module B8) refers to GHG emissions associated with the user's utilisation of the buildings or infrastructure during the use stage, excluding B6 and B7. These must be clearly identified as 'operational carbon' or 'user carbon' within the scope if addressed.

[1] For these carbon definitions, we only address GHGs with global warming potential (GWP) assigned by the Intergovernmental Panel on Climate Change (IPCC), e.g. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

[2] A0 is generally assumed to be zero for buildings. However, for infrastructure projects A0 can include ground investigations and activities associated with designing the asset.

[3] Demolition of existing structures or buildings must be separately identified and included in module A5.

1 Introduction

1.1 Background

Climate change is the greatest environmental challenge of our time. Global warming due to human-generated **greenhouse gas (GHG)** emissions into the atmosphere, referred to as **carbon emissions**, will have severe adverse environmental, biodiversity, social and economic 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, aim to restrict the impact of global warming by reducing and mitigating carbon emissions. At COP26 in Glasgow in 2021, pledges from 153 countries meant that over 90% of the world's GDP is now covered by commitments to achieving net zero. This means limiting carbon emissions so that they are balanced or exceeded by carbon removals such as afforestation or carbon capture and storage. Reducing carbon emissions also contributes to addressing both resource depletion and pollution.

The built environment is responsible for almost 40% of global carbon emissions, including buildings and infrastructure assets, and embodied and operational carbon (UNEP, 2022). In the UK, the UK Green Building Council (UKGBC) considers the built environment to be directly responsible for some 25% of the UK's consumption-based GHG emissions (Arup & UKGBC, 2021). Professionals working in this industry have a responsibility to work together to reduce this figure and identify where reductions in carbon emissions can be made. A consistent approach to measuring and reporting carbon throughout the life cycle of a built asset is key to achieving this. That approach is what is provided by this standard.

The metric for assessing the climate change impacts of GHG emissions is **global warming potential (GWP)**. GHGs include several gases that cause global warming, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and gases commonly used as refrigerants and insulation blowing agents. These gases each produce different levels of damage to the atmosphere, but are all expressed, for ease of use, in units of CO_2 equivalent over a 100-year timescale (CO_2e), often referred to as 'carbon impacts' or 'carbon'.

Built environment carbon impacts are mostly attributable to either operational or embodied carbon emissions. **Operational carbon impacts** result from energy and water consumption in the day-to-day running of a built asset, be it a building or infrastructure asset. **Embodied carbon impacts** arise from sourcing, manufacturing and installing the materials and components that make up a built asset, and also include the lifetime emissions from maintenance, repair, replacement and ultimately their demolition or deconstruction, waste treatment and disposal. In addition, there are also **user carbon impacts** from the activities of the users of a built asset, outside of the use of energy and water used to operate the asset, for example the impact of commuting to an office building or the impact of vehicles using a road, which produce further user-related emissions.

Together, operational, embodied and user carbon are known as **whole life carbon (WLC)**. The UN Environment Programme estimated that in 2021, embodied carbon was responsible for some 12% and operational carbon approximately 28% of global CO_2 emissions.

The built environment industry has, so far, mainly focused on operational carbon through energy reduction targets in building regulations (such as Part L in the UK), planning requirements from local authorities and sustainability assessment rating schemes (BREEAM, SKA and LEED, for example), with embodied carbon assessment much less common. However, since the publication of EN 15978, the European Standard on building-level environmental impacts (adopted as a British Standard in 2011, with an update due 2024); the first edition of this RICS standard (*Whole life carbon assessment for the built environment*, 2017); and EN 17472 for assessing infrastructure-level impacts (adopted as a British Standard in 2022), this has started to change across the built environment sector, both in the UK and globally.

1.2 What is a whole life carbon assessment?

Whole life carbon refers to the carbon impacts over the entire life cycle of a built asset, from its construction through to its end of life. A **whole life carbon assessment (WLCA)** is the calculation and reporting of the quantity of carbon impacts expected throughout all life cycle stages of a project, but also includes an assessment of the potential benefits and loads occurring beyond the system boundary.

The project life cycle stages are described in section 2.1, using the modular structure provided in EN 15978, EN 17472, EN 15804, EN 15643, ISO 21931 Parts 1 and 2, and ISO 21930.

WLCAs should be integrated into project planning and cost planning from the outset, developed in collaboration with the wider project team and updated as the project evolves. WLCAs can be carried out during any project phase, using generic information in the early design phases before evolving to more specific data as the design becomes more developed.

A WLCA aids decision making during the design, procurement, construction and use phases of a project, enabling built assets to achieve the lowest carbon impacts across all life cycle stages. National and local legislation is already evolving to include WLCAs. This standard ensures that WLC assessors using it are provided with data to inform decision making.

A WLCA not only helps identify the significant causes of carbon impacts for a project, but has other benefits such as integrating carbon considerations into design decisions, supporting long-term life cycle thinking beyond project completion and encouraging a fuller, more detailed understanding of the supply chain.

A high-level overview of the process for completing a WLCA is shown in Figure 1.

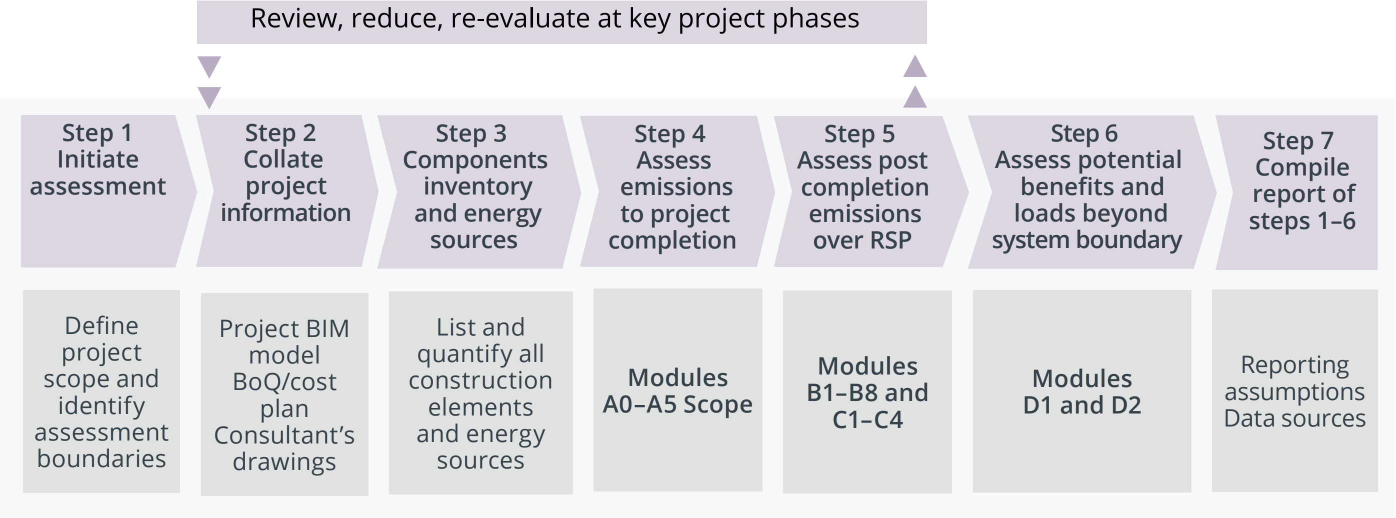


Figure 1: Recommended steps for reporting on whole life carbon assessment; this sequence should be repeated at various project phases (see section 2.3)

1.3 Application of this standard

This standard sets out an RICS-approved technical methodology for assessing the carbon impacts from buildings and related infrastructure assets/civil engineering works throughout their life cycle.

All those undertaking the role of WLC assessor must follow the mandatory requirements included in this methodology in order for the WLCA to be compliant with this standard.

RICS members undertaking assessments should advise their clients or employers on the benefits of using this standard.

If an RICS member is required to undertake a WLCA in accordance with a methodology that conflicts with or differs from this standard (for instance because of statutory, regulatory or other authoritative requirements), they may do so, provided that in complying with the alternative methodology, the member's professional obligations set out in the RICS Rules of Conduct are met.

In such cases, the member undertaking the assessment must ensure that it is clear in their report which standards are being adopted, and the reason for the departure from this standard.

While this standard is intended for RICS members, one of its key objectives is adoption by the wider industry to enhance the quality, comparability and accuracy of data. For this reason, its adoption by other built environment professionals is encouraged. Active adoption of this standard by clients commissioning WLCAs, and statutory and regulatory authorities, is also encouraged.

The methodology in this standard is globally applicable. While the numerical assumptions provided are based on UK locations and standard practices, by applying appropriate geographical adjustments highlighted in this standard, the requirements and guidance can be applied in other countries.

1.4 Scope of this standard

This standard can be applied to any type of construction or built asset involving any of the following:

- new construction/new-build assets
- demolition of existing and construction of new assets
- retrofit/refurbishment of existing assets
- masterplans with multiple built assets, including associated project infrastructure assets and civil engineering works, or
- fit-out of built assets.

1.4.1 Asset types covered

This standard is applicable to all kind of built assets, including all types of buildings, small projects, infrastructure assets/civil engineering works (see Appendix D for a classification of infrastructure assets based on International Cost Management Standards 3 (ICMS 3)) and masterplans.

1.4.2 Assessment scope

This standard addresses all element and component categories that make up a built asset, across every life cycle stage: from extracting the raw materials and manufacturing construction products, through construction and operation, to recovery or disposal at end of life. It also separately assesses the potential loads and benefits beyond the system boundary in the next life cycle.

All aspects of WLCAs covered by this standard are explained and put into context. This includes the timing and frequency with which WLCAs should be undertaken, and what is involved in undertaking an assessment. Practical guidance and requirements for quantifying carbon and reporting the results are also provided.

1.4.3 Supporting guidance

This standard is not intended to be an introductory guide. A list of additional guides and resources for WLC assessors wishing to gain a more detailed understanding are listed in Appendix Q. UKGBC also offer a range of Bitesize Learning Guides on the topic, which demystify key carbon concepts. Some of the standards from CEN, CIBSE and other non-RICS sources referred to in this standard may require payment for access and are included for additional information only.

1.4.4 Who can be a WLC assessor?

WLCAs may be undertaken by RICS members such as cost consultants, quantity surveyors and building surveyors; other members of the design team, such as architects or engineers; or a specialist consultant within or reporting to the design team. The term **WLC assessor** is used throughout this standard to refer to the person undertaking the assessment. It is expected that most WLC assessors will either undertake assessments using this standard directly or by using software tools that function in compliance with its methodology. WLC assessors should ensure that software used for WLCAs complies with this standard.

1.4.5 European context for this standard

CEN is the European standards body, and its Technical Committee CEN/TC 350 develops standards related to sustainable construction. As set out in Appendix L, this standard aligns very closely with the following European standards, which have been developed by CEN/TC 350 (European standards are prefixed with 'BS' for British Standard in the UK):

- EN 15978 for building-level environmental assessments
- EN 17472 for infrastructure project sustainability assessments
- EN 15643 framework for sustainability assessment of buildings and civil engineering works, and
- EN 15804 for environmental product declarations (EPDs) of construction products and materials.

These European standards cover assessments relating to many more environmental impact indicators than climate change and carbon emissions. This standard explicitly addresses the assessment of climate change impacts only. However, the calculation principles it sets out can be expanded to cover any or all of the environmental impact indicators specified in these European standards, such as ozone depletion potential or acidification potential.

In the event of a discrepancy between this standard and the international standards listed in Appendix L, this standard must take precedence if the assessment is described as being compliant with it.

1.5 Core principles of compliance with this standard

The following are the core principles of undertaking WLCAs in compliance with this standard:

- **Consistent WLC measurement**: WLCAs need to be reliable and comparable. This requires consistency in the methodology, assumptions and data used. Objectives include increasing the reliability of WLCAs by providing a solid source of reference for the industry and making WLCAs more 'mainstream' by enhancing their accessibility, thereby encouraging greater engagement and uptake by the built environment sector.

- **Practical implementation**: This standard emphasises the practical implementation of the existing and widely-accepted environmental performance assessment structure of EN 15978, EN 17472, EN 15643 and EN 15804, but additionally provides guidance on sources of data and assumptions that should be used for all assessments in the UK. This is to facilitate consistency in calculations, even during the early design phase where detailed project-specific information might not yet be available. This will enable the UK industry, together with local authorities and governments, to set targets to reduce WLC and measure their performance against these targets. Where other regions are able to identify relevant sources of data and assumptions to ensure consistency, regional targets could also be set outside the UK.
- **Comprehensive modular structure**: The asset life cycle is broken down into different life cycle stages and modules, and buildings and infrastructure are organised into element categories. This addresses all aspects that influence WLC in a structured way and enables more granular comparisons than simply at the project level. It also enables flexibility in the size, location and number of assets to be examined without compromising consistency.
- **Integration of WLCAs into project design and delivery for more effective carbon management**: For whole life principles to be integrated into design, procurement and construction processes and beyond – and for project teams to be engaged in a timely fashion – WLCAs should be carried out at key project phases from concept design to project completion. Appropriate timing and sequencing of WLCAs will help identify carbon reduction opportunities and monitor a project's progress in achieving them.
- **Aligning cost planning and WLCAs**: Ideally, WLCAs will be undertaken in parallel with life cycle costing within the framework of RICS' New rules of measurement (NRM) or International Cost Management Standard 3 (ICMS 3). Refer to section 2.5 for more details.
- **Interaction with carbon management**: In the UK, this standard could be considered as a nationally recognised and appropriate GHG assessment methodology (which complies with EN 15978, EN 17472 and EN 15643) for GHG quantification, as required in the carbon management approach set out in PAS 2080:2023, where target setting, reduction, reporting and leadership are also considered.
- **Integration with tools and building information modelling (BIM)**: The requirements and recommendations provided in this standard can be incorporated into WLC, embodied carbon, operational carbon or life cycle assessment software tools, whether standalone or integrated with BIM, constituting the wireframe for carbon calculation algorithms in the UK and elsewhere. This will improve the comparability and usability of WLCA results, and contribute to achieving greater consistency across different assessment tools and software.

- **Assessing, not guessing**: There may be preconceptions, for example, that natural, local or lightweight materials have lower embodied carbon. However, embodied carbon is complex, and it is important to assess whether proposed options will really achieve reductions in upfront, embodied and whole life carbon for a particular asset.
- **Carbon cost/benefit**: Assessing WLC is a holistic process where carbon costs and carbon benefits are assessed in relation to each other, in order to optimise overall carbon performance. For example, louvres or insulation may have an operational carbon benefit over an asset's life cycle, which should be assessed in relation to the carbon costs of the original installation, anticipated maintenance and replacement cycles, and end of life (see section 2.4).

1.6 Wider benefits of WLCAs

Under the overarching objective of facilitating a lower-carbon and more resource-efficient built environment, this standard is expected to have a number of additional beneficial effects:

- **More accurate scope reporting** under the Greenhouse Gas Protocol (see also Appendix A), which covers:
    - **Scope 1**: 'direct emissions', i.e. emissions from sources that an organisation owns or controls directly, for example fuel combustion, vehicles and fugitive emissions.
    - **Scope 2**: 'indirect emissions', i.e. emissions that an organisation causes indirectly when the energy it purchases and uses is produced by others, for example purchased electricity, heat and steam.
    - **Scope 3**: 'other indirect emissions', i.e. purchased goods and services, business travel, employee commuting, waste disposal and use of sold products.

    For its owner or user, embodied carbon for a building or infrastructure asset/civil engineering works usually falls under scope 3 (purchased goods and services), with operational carbon falling under scopes 1 and 2, and user carbon usually under scope 2 or 3. See Appendix A, which describes how WLCAs relate to GHG accounting using GRESB, CRREM or PCAF, and provides an illustration of how different stakeholders may cause or influence scope 1, 2 and 3 emissions within different life cycle modules. For companies that report their scope 1, 2 and 3 emissions, a WLCA will provide data that can be used for this reporting, particularly for companies involved in the built environment sector.

- **Benchmarking**: Conducting WLCAs within a given region in accordance with this standard will put all studies on the same basis and provide greater consistency of results. This will enable meaningful comparisons at different levels:
    - between built assets
    - for each building element category
    - for each life cycle stage and
    - for entire projects throughout their life cycles.

Collecting carbon assessments in a structured fashion that can be used to populate a database will lead to sensible benchmarking. This will set the bar for carbon performance in the built environment. RICS is partnering with other organisations to develop an online data gathering platform, the Built Environment Carbon Database (BECD), where the results of assessments in accordance with this standard can be reported so that benchmarks can be developed in the UK.

- **Baselining**: When a WLCA for a project is carried out during its early design phase, it provides a baseline that can be compared to the results of later assessment iterations. This ensures effective monitoring of the carbon impact of the project as it progresses through the design and construction phases.
- **Carbon target setting**: Once credible benchmarks are in place, relevant limits and targets can be set for the upfront, embodied and whole life carbon performance of built assets. The incorporation of such targets into sustainable development policies for the built environment, planning requirements, building rating schemes, contractual obligations and legislation/building regulations will help drive down carbon impacts.
- **Encouraging longer-term thinking**: Inherent in WLCAs is an examination of the carbon impacts of maintenance, repair and replacement for a built asset over its entire life cycle. Assets that use durable materials and are well-detailed and soundly constructed, requiring less maintenance and replacement, can have lower WLC impacts. Project teams, by thinking about the long term and considering likely future climate change and the development of appropriate future adaptation strategies during the design phase, will also improve the future resilience of built assets, and reduce carbon impacts and waste.
- **Encouraging circular economy principles**: WLCAs promote circular economy principles and the benefits of reuse by prioritising the post-end-of-life reuse of materials, components and systems, as well as preferring retrofit and refurbishment over new build. This involves quantifying reuse, recycling and/or recovery potential.
- **Better linkage with data and software tools**: Advancements in the quality, availability and scrutiny of carbon data, as well as its integration with BIM, should further improve the accessibility, accuracy and simplicity of conducting WLCAs.
- **Supporting the transition to net zero**: The UK Net Zero Carbon Buildings Standard (which is currently in development) is broadly aligned with this standard's methodology to assess upfront, embodied, operational, user and whole life carbon.

1.7 Mandatory requirements for compliant WLCAs

Mandatory requirements throughout this standard are presented in bold and use the word **must**. Requirements convey objectively verifiable criteria to be fulfilled, which cannot be deviated from in order to comply with this standard. This is equivalent to the use of 'shall' in British, European and international standards. Recommendations in this standard use the word 'should' and recognise that there may be acceptable alternatives to achieving the same or an even better outcome. Any content that does not use the word 'must' or 'should' is for information purposes only.

Any compliant WLCA must comply with all relevant requirements for that project phase and project type set out in this standard.

Where WLCAs depart from the recommendations in this standard, they must only do so for a justifiable reason, which must be recorded as part of the assessment.

1.8 Supporting documents

The following documents are included as supplementary materials to be used in conjunction with this standard:

- Building element categories
- Reporting template – buildings
- Reporting template – infrastructure
- Reporting template – summary
- MEP – supplementary tables
- Energy – supplementary tables

Links are also provided whenever supporting documents are mentioned.

1.9 Effective date

This standard becomes effective on 1 July 2024.

2 Key initial considerations when undertaking a WLCA

In this section, the modular structure of a WLCA is described in detail, and how this interrelates to the overall project life cycle phases is explained. It identifies at which points a WLCA should be undertaken, highlighting the significance of doing so during early design stages. It then discusses the importance of presenting WLCA data alongside project cost information, through ICMS 3.

A WLCA is intended to examine all carbon impacts from production of materials, construction, use and disposal of a built asset over its entire life cycle. This approach also helps to identify the best opportunities for reducing overall lifetime impacts and avoid any unintended consequences from focusing on operational or embodied carbon alone. For example, a WLCA would show whether the embodied carbon burden of installing triple glazing rather than double is less than the operational carbon benefit resulting from the additional pane. A WLCA comparing traditional ballasted track with sleepers against a concrete slab track would indicate the most carbon-efficient solution over the whole life of a railway infrastructure asset, accounting for maintenance and replacement impacts as well as the carbon emitted up until handover.

Therefore, a WLCA should provide an understanding of the carbon costs and benefits of different design choices. This then helps to minimise lifetime carbon impacts and support the built environment sector’s efforts to follow the trajectory to net zero by 2050.

2.1 The modular structure of a WLCA

All WLCAs follow a modular structure for carbon reporting, which breaks down the built asset's life cycle into stages and modules. Some modules are broken down further into sub-modules; these are explained in more detail in the relevant life cycle stage in section 5.

Figure 2 sets out the modular structure for WLCAs.

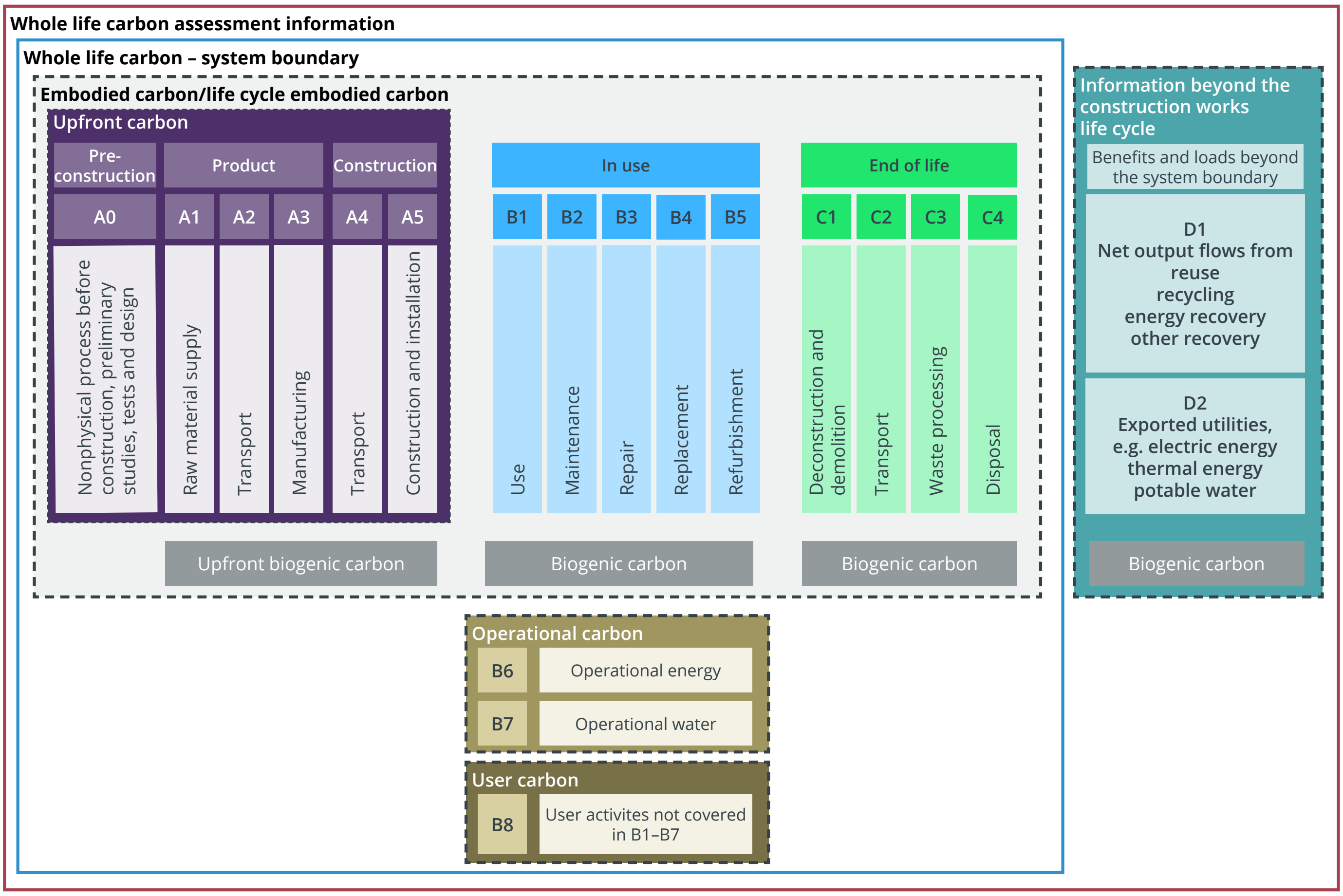


Figure 2: Building and infrastructure life cycle stages and information modules (adapted from EN 15978, EN 17472 and EN 15643, with additions to illustrate biogenic carbon)

Emissions and removals of all types of carbon (fossil carbon, land use and land use change (LULUC) carbon, and biogenic carbon) are assessed and reported in the modules in which they occur. However, as Figure 2 shows, when reporting upfront carbon (as described below) the sequestered biogenic carbon stored within construction products incorporated into an asset is not included, but is reported separately.

Here is a detailed breakdown of how the life cycle stages of a built asset translate into modules for carbon reporting:

- **Life cycle stage A:** covers all carbon emissions and removals from any activities necessary to complete the construction of the asset.
  - **Module A0 (pre-construction stage)** covers non-physical pre-construction activities, such as surveys and activities associated with the design of the asset. These can be a significant economic cost, but for buildings do not normally have a significant environmental impact. A0 is therefore generally assumed to be negligible for buildings. However, for infrastructure projects or where the design team uses air travel or sets up a project-specific office, A0 may be more significant.

  - **Modules A1–A3 (product stage)** cover the extraction, transportation and manufacturing processes necessary to produce any construction products, including components and MEP, required to construct the asset.
  - **Modules A4–A5 (construction stage)** cover transportation of construction products and all construction processes, including wastage, up to project completion. Module A5 also includes any on-site demolition or strip-out works required at the beginning of the project.
- **Life cycle stage B:** covers all carbon emissions and removals that occur over the in-use stage of the asset.
  - **Module B1** covers direct emissions and removals from construction products, such as emission of blowing agents from insulation, refrigerant leakage from MEP equipment or removal of CO_2 through carbonation of concrete.
  - **Modules B2–B4** cover material-related emissions that occur from maintenance, repair and replacement of any construction products, components, or elements of the asset over the **reference study period** (see below and section 4.2).
  - **Module B5** covers any refurbishment or change in performance of the asset (e.g. retrofit/refurbishment or extension) planned at the outset of the project to occur at some point after construction is completed.
  - **Module B6** covers the energy use of the asset over the in-use stage.
  - **Module B7** covers water use over the in-use stage.
  - **Module B8** covers user activities not included elsewhere and could include, for example, emissions from vehicles using a road or the impact of commuting to an office building over the in-use stage.
- **Life cycle stage C:** covers all ‘end-of-life’ impacts.
  - **Modules C1–C4** cover impacts during the end-of-life stage of an asset. This includes deconstruction or demolition, waste processing, recovery or disposal and associated transport.
- **Life cycle stage D:** covers potential benefits and loads beyond the system boundary.
  - **Module D1** covers the potential carbon loads and benefits beyond the system boundary from reuse, recycling, energy recovery or landfilling of any material arising from the construction (A4–A5), use (B2–B5) or end-of-life (C1–C4) stages.
  - **Module D2** covers the potential carbon benefits beyond the system boundary of any utilities exported from the asset during in-use stages B6–B8, such as generated electricity or treated water.

The terms below describe the modular project boundaries used when calculating and reporting the carbon impacts of a project life cycle, as identified in Figure 2 (see Carbon definitions for whole life carbon assessments for technical definitions):

- **Upfront carbon**: modules A0–A5, covering all impacts up to the completion of the project, but excluding any sequestered biogenic carbon stored within construction products incorporated into the asset, which is reported separately.
- **Embodied carbon**: modules A0–A5, B1–B5 and C1–C4, all material-related impacts.
- **Operational carbon**: modules B6 and B7, impacts from energy and water use.
- **User carbon**: module B8, impacts from user activities.
- **Whole life carbon (WLC)**: covers modules A, B and C. This is the system boundary for a WLCA over the asset's life cycle. However, a full assessment will also include module D, which is reported separately.
- **Reference study period (RSP)**: for WLCA purposes, the RSP is a standardised period over which the in-use stage (modules B1–B8) of the built asset is analysed, and typically differs from country to country. In the UK, and for WLCAs compliant with this standard, different asset types use different RSPs. See section 4.2 for a full explanation.

2.2 Project phases

Project phases, from strategic design to project completion and beyond, are explained in different ways in different standards and regions. Table 1 shows the terms for the key project phases used in this standard and how they relate to other approaches to project phasing, such as the RIBA Plan of Work and ICMS 3.

<table>
<tr><th>Source</th><th colspan="10">Work stages</th><th>End of life</th></tr>
<tr><td rowspan="2">RICS whole life carbon standard 2023 (project phases)</td><td colspan="4">Early design phase</td><td colspan="3" rowspan="2">Technical design phase</td><td rowspan="2">Construction phase</td><td rowspan="2">Post-completion phase</td><td rowspan="2">In-use phase</td><td rowspan="2">End-of-life phase</td></tr>
<tr><td colspan="2">Strategic design phase</td><td colspan="2">Concept design phase</td></tr>
<tr><td>RICS whole life carbon standard 2023 (assessment type)</td><td colspan="6">Pre-construction forecasts</td><td>At tender assessment</td><td>During construction assessment</td><td>Post-completion assessment</td><td>Renewal forecast during use</td><td>End-of-life forecast as deconstructed assessment</td></tr>
<tr><td>ICMS 3 project status</td><td colspan="5">Initiation and concept phase</td><td colspan="2">Design phase</td><td colspan="2">Construction and commissioning phase</td><td>In use</td><td>Close to end of life</td></tr>
<tr><td>ICMS 3 life cycle costs and carbon emissions</td><td colspan="6">Pre-construction forecasts</td><td>At tender assessment</td><td>During construction assessment</td><td>Post-completion assessment</td><td>Renewal forecast during use</td><td>End-of-life forecast</td></tr>
<tr><td>RIBA Plan of Work (2020)</td><td>0 Strategic definition</td><td>1 Preparation and briefing</td><td colspan="2">2 Concept design</td><td>3 Spatial coordination</td><td colspan="2">4 Technical design</td><td>5 Manufacturing and construction</td><td>6 Handover</td><td>7 Use</td><td></td></tr>
<tr><td>BIM Levels of Development (LOD) (AIA 2008)</td><td colspan="2">LOD 100 Pre-design/ Conceptual</td><td colspan="3">LOD 200 Schematic Design/Approximate Geometry</td><td>LOD 300 Design Development/ Precise Geometry</td><td>LOD 350 Construction Documentation</td><td>LOD 400 Construction Stage/ fabrication</td><td>LOD 500 As built</td><td></td><td></td></tr>
<tr><td>BS 8536:2022 (Infrastructure)</td><td>Strategy</td><td>Preparation and brief</td><td>Concept</td><td>Definition</td><td colspan="3">Technical design</td><td>Manufacturing and construction</td><td>Handover and closure</td><td>Use</td><td></td></tr>
<tr><td>PAS 2080:2023 and Value Toolkit work stages</td><td>Need</td><td colspan="3">Optioneering</td><td colspan="3">Design</td><td colspan="2">Delivery</td><td>Operation</td><td>Purpose and performance review</td></tr>
</table>

Table 1: Key project phases used in this standard and their relationship to other approaches

A compliant WLCA should be undertaken at the following key project phases.

- **Concept design phase**: Pre-construction forecasts should be used as the project baseline for ongoing carbon reporting and progress tracking throughout the project.
- **Technical design phase**: Pre-construction forecasts should be used to evaluate the evolving design, and at-tender assessments should be used to evaluate tenders.
- **Construction phase**: As specific products are chosen or the design is adjusted, pre-construction forecasts should be reviewed and updated to monitor construction variations.
- **Post-completion phase**: A post-completion assessment should be used to check the carbon reductions predicted in the pre-construction and at-tender forecasts have been achieved.

2.3 When to undertake WLCAs

WLCAs should be undertaken in a sequential fashion during the early design, technical design, construction and post-completion phases of a project, in order to be integrated into the decision-making framework for a project. The WLCA process can start as early as the concept design phase. A concept design phase WLCA for an asset or project is recommended, in order to establish a carbon impacts baseline and identify the potential for carbon reduction while there is still significant capacity to influence decisions. As the project proceeds, carbon reduction opportunities become fewer, have reduced impact and are potentially more expensive to implement. This is illustrated in Figure 3.

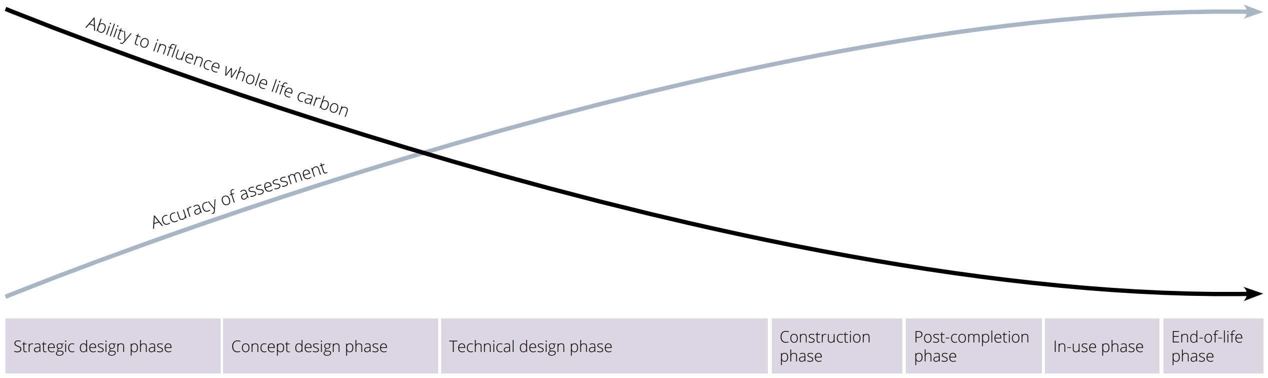


Figure 3: As the project progresses, the ability to influence whole life carbon decreases but the accuracy of assessment increases

Updated WLCAs during later project phases are strongly recommended in order to monitor performance against the initial carbon emission baseline as the project develops, for example as material efficiency measures are implemented or manufacturer-specific products are chosen. It is also important to check the proposed asset has been constructed as designed, and changes have not been made during the construction process that affect carbon impacts, by providing an as-built WLCA at the project's practical completion.

Increasing levels of detail in the design and specification of the built asset will become available to the WLC assessor as the project progresses through the technical design and construction phases. If the scope of the project changes, comparisons with any baseline assessment should be reviewed for consistency. The data sources and approaches suggested throughout this standard are recommended to achieve the highest possible quality, accuracy and completeness. It should be recognised that calculations are predictions until accurate measured data becomes available.

Focusing on improvements in both embodied carbon and operational carbon impacts simultaneously helps to achieve the optimum overall carbon reductions. Figure 4 shows an indication of the improvements that are possible, and the importance of examining the effect on both embodied carbon and operational carbon when making design decisions. It also illustrates the increasing proportion of embodied carbon in WLC as operational energy consumption is reduced.

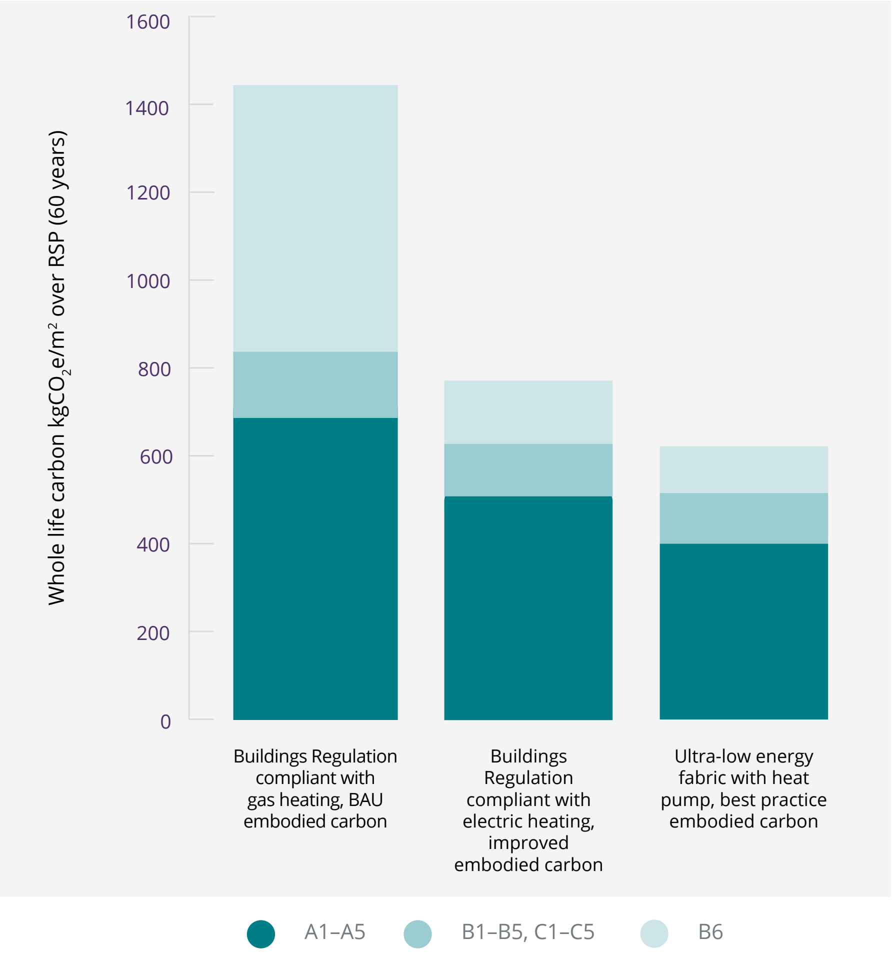


Figure 4: Comparison of three options for a residential building, showing the reductions in whole life carbon that may be possible with different reduction strategies (decarbonised scenario)

2.4 Evaluating design options during early project phases

Optioneering describes the process by which the project team considers potential options in depth to find the preferred solution. During the **concept design phase** in particular, it may be helpful to carry out partial WLCAs focusing on options for one or more major elements, in order to consider the comparative carbon impacts before committing to a particular course of action, for example when deciding on structural elements.

It is also important that a full project WLCA is done during the early design phases to see where further improvements can be found at a strategic level while the design is still sufficiently flexible. For buildings, the substructure and superstructure are usually a more significant proportion of embodied carbon than other elements, so comparative carbon studies during the early design phase can be hugely beneficial, optimising efficiency benefits before specifications are locked in.

For example, options for the building envelope can be assessed for both embodied and operational carbon impacts to fully understand the implications of any choice. Carbon emission cost/benefit studies should be undertaken to ensure the optimisation of capital cost, total cost of ownership, upfront carbon, embodied carbon and in-use carbon benefits such as improved thermal performance, reduced energy use, increased durability or lower climate impact. This approach can help minimise a project's WLC, and also better predict lifetime maintenance and energy use costs.

The concept design phase is also the appropriate phase to assess a potential retrofit or refurbishment project compared to a new-build option. In the majority of cases, there will be a carbon emission benefit to retrofitting or refurbishment over the course of the RSP compared to demolition and redevelopment or new-build. Comparative assessments between refurbishment and new-build options should be done to clarify this.

A partial WLCA does not constitute a WLCA in full compliance with the requirements set out in this standard. Any partial WLCA should use the same reporting boundaries as a full WLCA to ensure transparency and consistency in decision making.

2.5 Presenting cost and carbon data

One benefit of integrating a WLCA process into the overall design process is the opportunity to make decisions based on a number of drivers, of which carbon impacts are an increasingly important one. ICMS 3 provides a consistent reporting taxonomy to support 'global consistency in presenting construction life cycle costs and carbon emissions'. The third edition is structured to provide the opportunity to break down cost and carbon data into the construction, renewal, operation and maintenance of built assets. When done at the early design stages, this will allow the identification of options with reduced carbon impacts for decision-making purposes.

ICMS 3 is referenced in this standard to ensure that a consistent approach is followed across standards. While this standard provides a consistent approach to calculating carbon impacts, it will be important to map the data between standards in specific situations. Table 2 provides mapping between the European standards life cycle modules used in this standard and Level 2 of ICMS 3, based on Figure H-1 in ICMS 3. An ‘Optional reporting aligned with ICMS 3, including uncertainty’ table is also provided in the accompanying Reporting template – summary document.

LCA to EN15978 & EN17472 & RICS professional standard		ICMS 3		
[A0]	Pre-construction stage	A|1	Acquisition	Life Cycle Carbon Emissions (LCCE)
[A1–A3]	Product Stage	C|2	Construction	
[A4]	Transport			
[A5]	Construction process			
[B4]	Replacement	R|3	Renewal	
[B5]	Refurbishment			
[B1]	In use			
[B2] – cleaning only	Maintenance – cleaning	O|4	Operation	
[B6]	Operational energy			
[B7]	Operational water			
[B8]	Other operational			
[B2] – other than cleaning	Maintenance – other	M|5	Maintenance	
[B3]	Repair			
[C1]	Deconstruction/demolition	E|6	End of life	
[C2]	Transport			
[C3]	Waste processing			
[C4]	Disposal			
D	Benefits and loads beyond the system boundary		Externalities	Externalities

Table 2: Mapping between a) EN 15978, EN 17472 and this standard’s life cycle modules, and b) Level 2 of ICMS 3

3 Types of projects and assessments

Different project types have different characteristics that may require changes in emphasis when conducting a WLCA. This section identifies particular issues that relate to the main project types. Sections 3.1–3.5 and 3.7–3.9 also apply to types of infrastructure assets, which are listed in Appendix D.

3.1 New construction/new-build assets, greenfield sites

For new-build assets, either buildings or infrastructure assets/civil engineering works, all life cycle stages must be assessed, including module D (which is reported separately). All building or infrastructure elements within the project site boundary (red line or equivalent) must be included in the WLCA. This includes any facilitating works and site preparation inside and outside of the asset footprint, but within the site boundary, and any upfront carbon of works required outside the site boundary to facilitate the project.

This is shown as asset 1 in Figure 5.

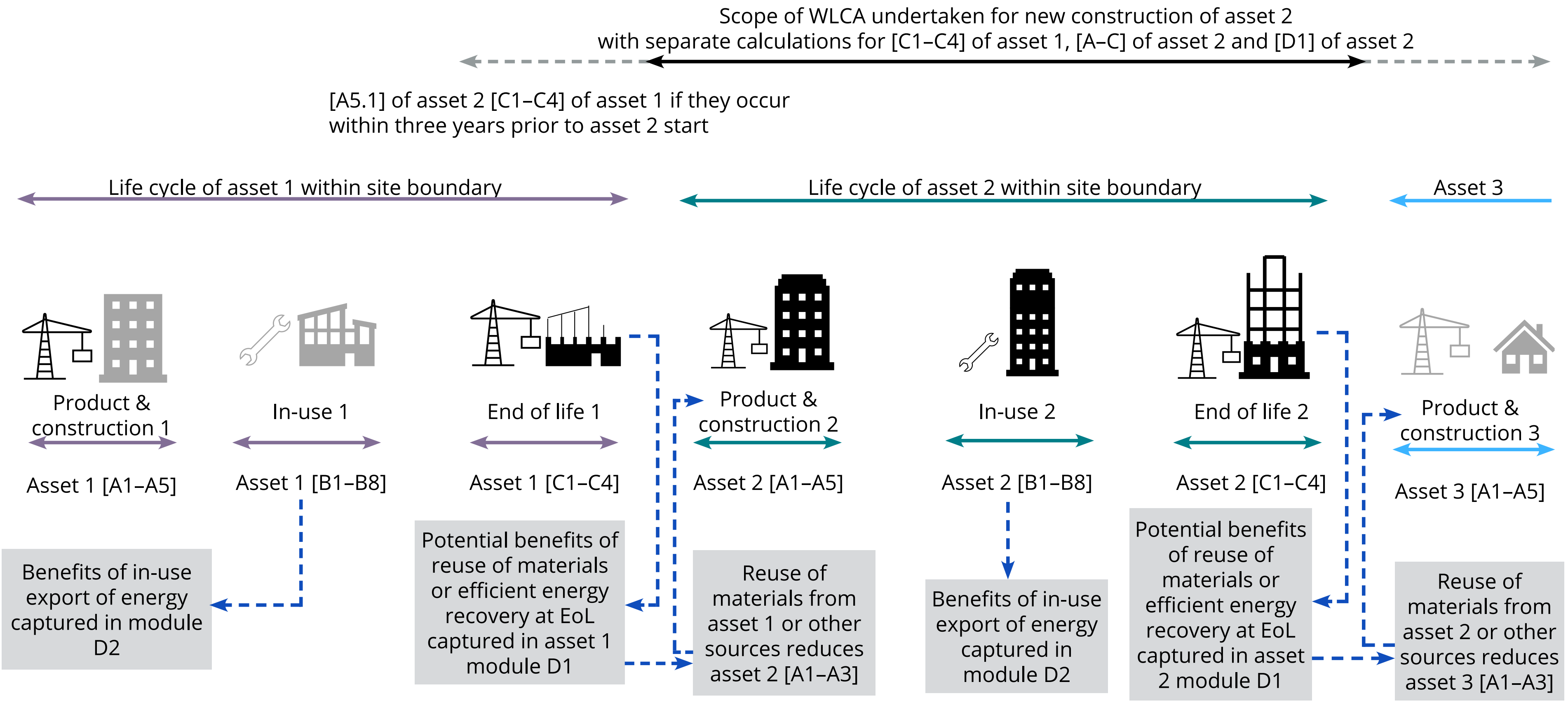


Figure 5: The life cycle stages of an asset and how they relate to successive new-build projects over sequential life cycles; this shows how the modular structure works over three generations of asset on a single site, and how they can interrelate to minimise impacts

3.2 Demolition, deconstruction and new construction

When any full or partial demolition or deconstruction of an existing structure is required, to facilitate the construction of a new asset within the designated site boundary or as an extension to the existing asset, the impacts associated with that demolition or deconstruction must be included in the WLCA in sub-module A5.1 (see section 5.1.4).

The reuse and refurbishment of existing structures is often the most efficient approach in terms of WLCA, as this approach minimises the need for new materials and reduces the amount of demolition waste. There should be an improvement in the product stage (A1–A3) emission figures if demolition is minimised and structures are reused, or the maximum amount of material from any demolition or deconstruction is recovered and used on site. If materials are recovered and used elsewhere, any benefit will be shown in D1.

Where a project is initiated on a brownfield site, emissions from any demolition that has already occurred via a previous site owner or event must still be considered within the scope of the WLCA and be reported in A5.1, if demolition occurs within three years of the sale or new proposal. If data is not available, use the standard assumption provided in section 5.1.4. This is shown as asset 2 in Figure 5.

3.3 Retrofit/refurbishment of built assets

The term **retrofit** is based on the relevant ISO 6707 definition: a 'modification to an asset in order to generate an improved condition'. There are multiple scopes of work related to retrofitting a built asset, depending on the extent of the works. Various ranges of new-build can be associated with a retrofit project, in addition to retaining any existing elements. Examples include roof extensions requiring no structural amendment or full new-build extensions with full structural additions. The purpose of the requirements and guidance provided here is to ensure that, despite differences in scope, the WLC impacts of a retrofit/refurbishment project can be measured consistently for decision-making and benchmarking purposes.

All retrofit/refurbishment projects should be treated as new projects, and must report against all life cycle stages and module D (reported separately) over the defined RSP.

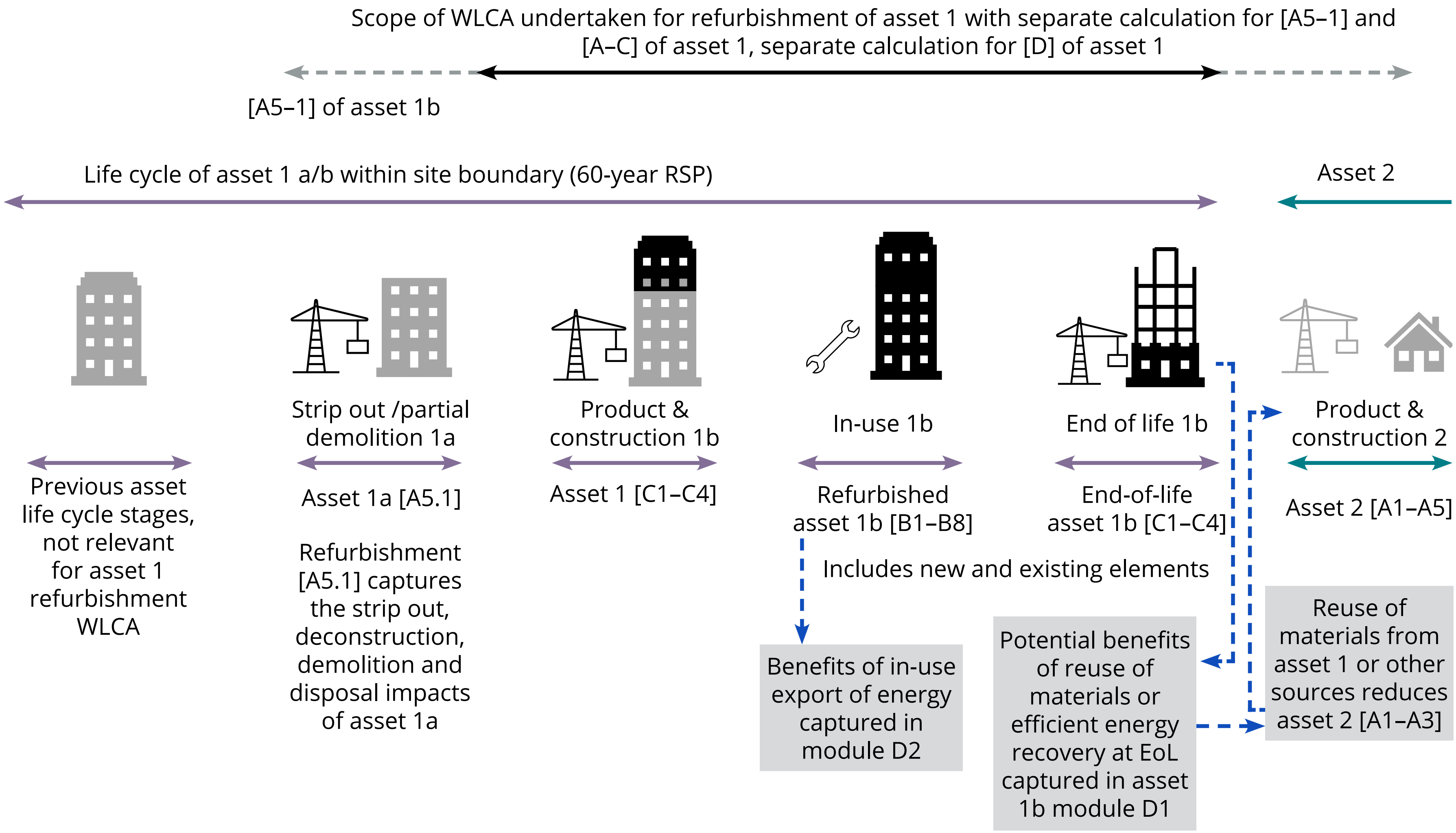


Figure 6: An illustrative life cycle sequence for a building that evolves through a subsequent refurbishment; it shows how that interrelates with the modular structure for each generation in the life cycle

Any demolition/deconstruction or alterations to facilitate the retrofit/refurbishment works, including removals and/or stripping out of elements, must be treated as pre-construction works and reported in the separate sub-module A5.1.

New material added to the asset or project will result in product and construction stage impacts, which must be reported in modules A1–A5. New material may also cause in-use stage impacts, such as for maintenance or replacement, which must be reported in module B. End-of-life impacts from new material must be reported in module C, and potential post-end-of-life benefits or loads outside the system boundary must be reported separately in module D.

Retained elements from the original building are assumed to have no impact from their previous manufacture included in the A1–A5 assessment of a retrofit/refurbishment.

However, retained elements may result in impacts during the in-use stage, such as from maintenance or replacement, which must be reported in module B; from their end-of-life impacts, which must be reported in module C; and from potential benefits or loads outside the system boundary from their recovery, which must be reported in module D.

This is relevant to material from demolition or retrofit/refurbishment processes, and to new elements and retained elements.

Whole life carbon reporting for a retrofit/refurbishment project must recognise the average carbon impacts across the total project gross internal area (GIA), as well as the constituent parts.

For example, for a completed project that is part retrofit/refurbishment and part new-build, the assessor should report the following in $kgCO_2e/m^2$ and tonnes CO_2e (tCO_2e):

- total project impacts
- impacts for the refurbished GIA (including demolitions or alterations within this GIA)
- impacts for the new, additional GIA (including demolitions or alterations within this GIA)
- any external works within the site boundary and
- upfront carbon impacts related to external works required outside the site boundary.

3.4 Assessments including a planned change of use or alteration

If a change of use is not planned in the RSP, predicted impacts from replacement cycles of elements that reach their end of life during the RSP are reported in module B4.

The like-for-like replacement of products and components over the RSP is the default requirement for an assessment, and is the type that must be used for all projects as the basis for benchmarking.

However, some assets are built with a change of use planned at the outset of the design process to occur during the RSP. In this case, an additional assessment should be made and the predicted impacts from the product and construction stages of the planned change should be reported in module B5. The resulting changes to the modelling in modules B1–B4, B6–B8, C1–C4 and D should be considered in the modules in which they occur over the rest of the RSP.

Where a planned change of use is considered, two assessments must be undertaken – one with and one without the planned change of use – in order to facilitate benchmarking.

When a planned change of use is actually carried out on a building with a WLCA, the existing assessment (with the planned change of use modelled in B5) should be reviewed, updated or replaced, depending on the suitability of the original assessment and the actual change of use proposed. For example, the asset owner may decide to undertake a facade upgrade as part of an extension that was not previously considered in B5 of the original assessment.

In a more detailed example, if additional storeys for an office building will be added in year 5, the building should first be assessed as-built and the $kgCO_2e/m^2$ GIA compared to office building benchmarks. An assessment should then be made of the building, with the expected impacts in year 5 of the demolition and end of life of the existing roof, and the materials required for the addition of the extra storeys, all reported in B5. For the new storeys, the impacts associated with the additional components over the remainder of the RSP (55 years) will be reported in the relevant modules, e.g. use (B1), maintenance and repair (B2/B3), replacement (B4) and end of life (C1–C4). Loads and benefits associated with the reuse or recovery of the additional components beyond the system boundary will be reported separately in module D1.

The impacts of operation for the additional storeys will be reported in B6, B7 and B8 (Figure 7).

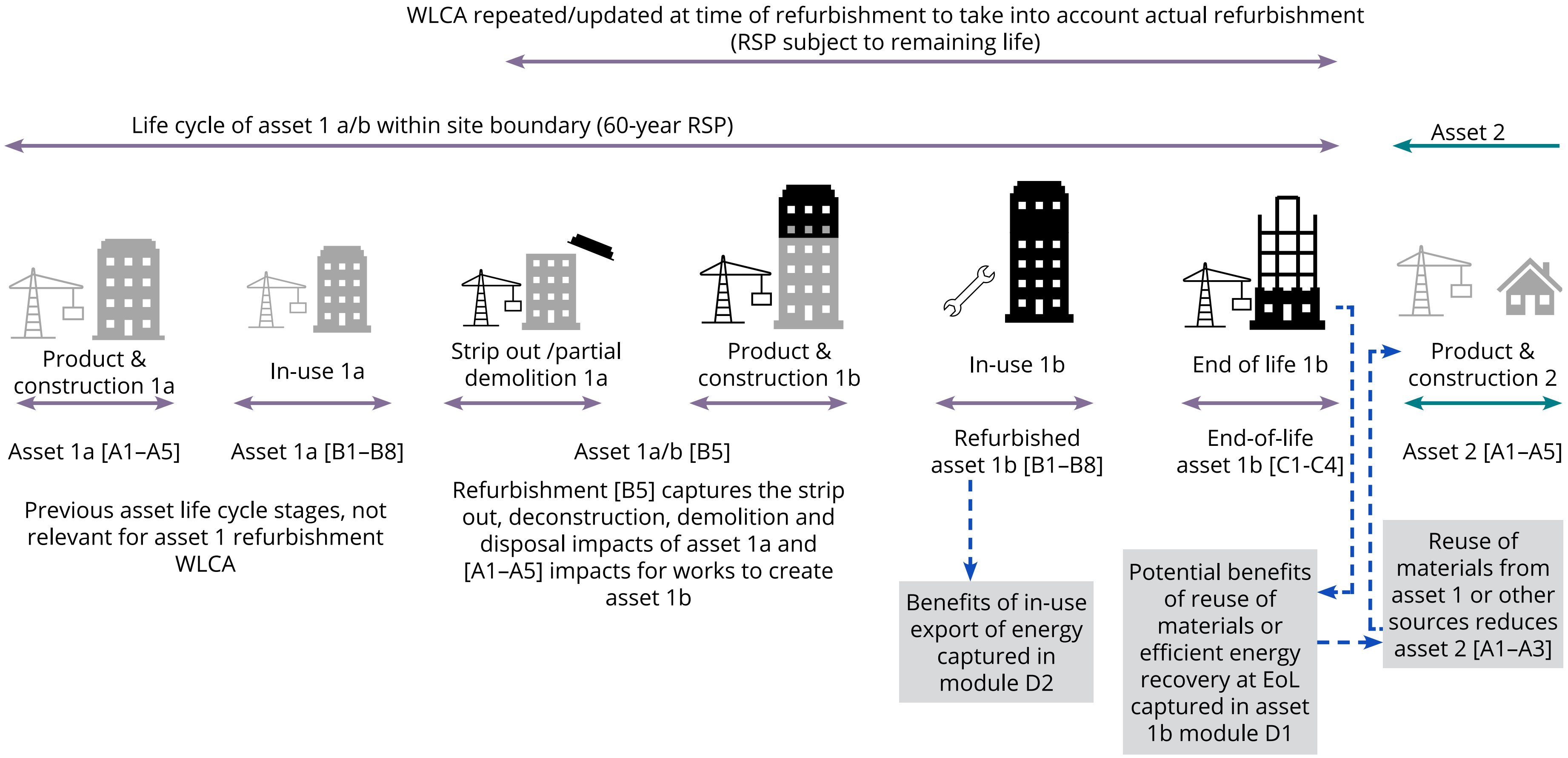


Figure 7: The life cycle for a change of use or refurbishment planned at the outset of the project

3.5 Masterplans or multi-asset developments

When carrying out a WLCA for multiple built assets within a residential, commercial, industrial or mixed-use masterplan, the following should be reported in appropriate units, including TCO_2e, $kgCO_2e/m^2$ or $kgCO_2e/m^3$, aligned with section 6.2 (see the accompanying reporting templates for full details):

- total project impacts
- each built asset as a separate entity (whether new-build, retrofit/refurbishment or combined)
- external works within the site boundary and
- upfront carbon impacts related to external works required outside the site boundary, e.g. improvements to or connections with the sewer network or power system upgrades.

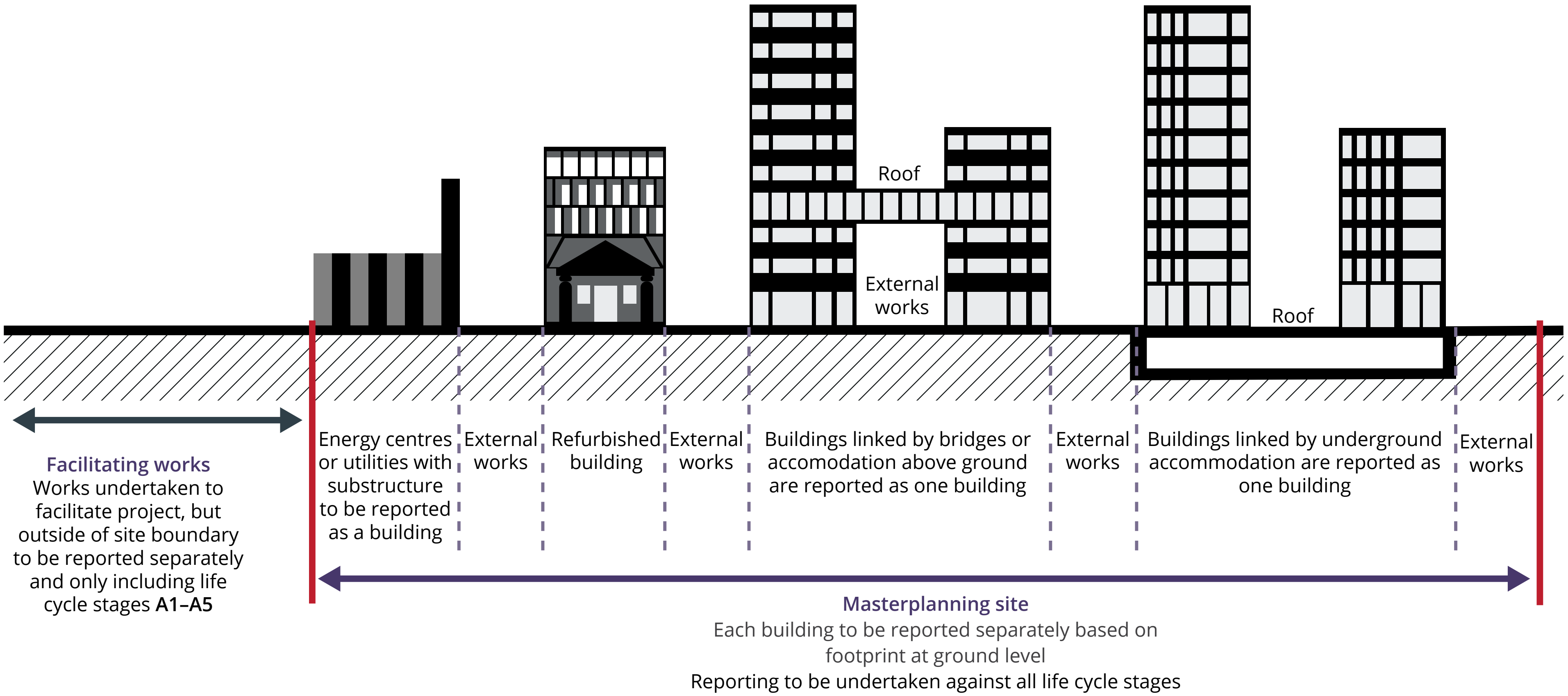


Figure 8: Reporting the constituent parts of a masterplan (source: Hawkins\Brown)

Where buildings across a masterplan are of the same type, one measurement can be taken to represent that unit and then extrapolated to report the total impacts.

The external works cover any area outside the building footprint but within the project boundary, reported using the external works category as described here and in section 4.3.

The scope of external works impacts reported must include all excavations and site preparations required to facilitate the new assets. All life cycle stages and module D (separately) must be reported, as it is assumed that the asset owner will be responsible for the WLC impacts of those elements, including the in-use and end-of-life stages.

For large masterplans, works are often required outside the site boundary, but the in-use and end-of-life impacts are not the responsibility of the asset owner. Impacts related to the product and construction stages of these scopes of work (A1–A5) should be reported separately, but later life cycle stages are not required to be included. Each building within a masterplan should be reported using building element categories as explained in this standard. Where individual buildings above ground share a basement below ground or are linked via an enclosed bridge above ground, they should be covered in one assessment to avoid inconsistencies.

When shared or communal spaces or facilities are involved, once impacts are calculated separately they can be allocated as appropriate based on reasonable proportions derived from respective GIAs, number of occupants or other metrics of capacity for each relevant built asset, taking into account their respective use types. This is not a primary reporting requirement, but may be useful when comparing the impacts of assets constructed on sites that do not require the same scope of external works.

3.6 Fit-out projects

For the purposes of this standard, the building elements included are as follows.

- **Shell and core**: includes facilitating works, substructure, superstructure (frame, external envelope including roof), central/building-related plant, core life safety and external works. It usually also includes the internal assemblies; finishes; and fixtures, fittings and equipment (FF&E) associated with central and/or shared areas of the building, including external works, circulation/escape cores, entrances, servicing or delivery zones, amenities, centralised catering and sanitary facilities.
- **Category A (Cat A)**: any site preparation works required for the shell and core build, as well as finishes (e.g. raised access floors, suspended ceilings), MEP and fixed FF&E outside of the shell and core scope.
- **Category B (Cat B)**: any site preparation works required for the Cat A works to convert the space to suit the tenant's requirements, e.g. internal assemblies to achieve a specific spatial layout; final finishes or specialist linings; loose FF&E; information, communication and technology/audio-visual (ICT/AV) equipment; moving or adding mechanical and electrical services to suit the cellularisation of the space; and the addition of meeting

room-type spaces. Cat B fit-outs can also include serviced areas such as dedicated kitchens, showers and/or changing rooms.

For a fit-out project, a WLCA can be undertaken for any scope of works, as long as the impacts are reported against the correct building element categories, all life cycle stages are assessed and the replacement cycles are reflected in the required RSP. When comparing design options using a WLCA, the measuring boundaries should be consistent.

Generally, lower carbon impacts over the RSP will be achieved when the scopes of shell and core, Cat A and Cat B for a project are clearly understood by each responsible party, even where they are delivered separately. This will reduce the likelihood of abortive works. For example, where a specific spatial layout is required for the Cat B fit-out but the MEP installed in the Cat A works is not suitable, carbon impacts are expended resolving the coordination issue and any consequent changes. This is often avoided with an owner/occupier asset, but better coordination between the parties in a landlord/tenant situation can often reduce overall carbon impacts. In addition, limiting the number of fit-out replacement cycles can have huge benefits (in the case of MEP, CIBSE's upcoming *Embodied Carbon in Building Services: Office HVAC* provides useful information).

Refer to Appendix F for more information about shell and core and Cat A scopes for MEP elements. The accompanying MEP – supplementary tables document provides MEP take-offs for commercial and residential shell and core and Cat A in a UK context.

3.7 Infrastructure assets/civil engineering works

Large infrastructure projects may consist of various sub-projects/assets. For instance, a railway project may include different constituent sub-projects/assets such as tunnels, tracks, bridges and stations.

Such sub-projects/assets should be assessed and captured individually, and all of them reported in the WLCA for the entire project, as shown in Figure 9.

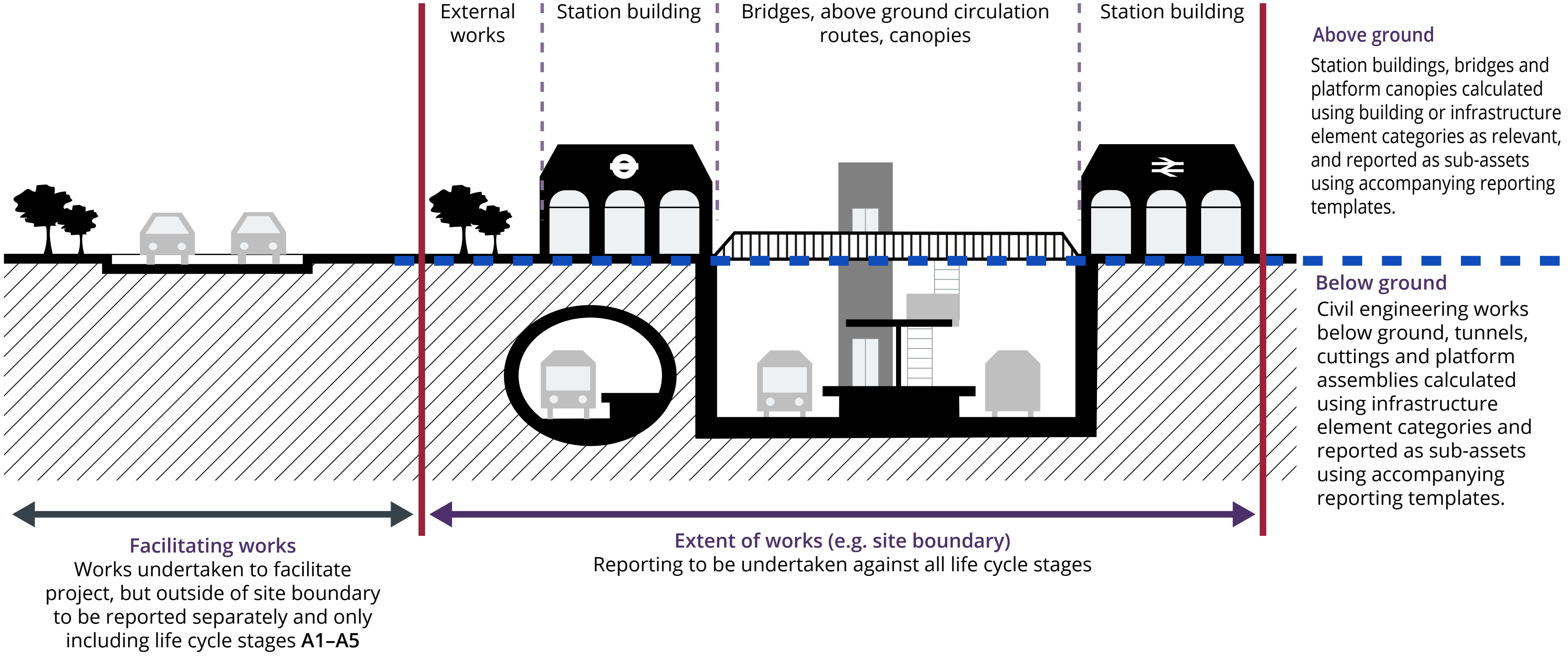


Figure 9: Example constituent parts of an infrastructure asset (source: Hawkins\Brown)

See Appendix D for a list of infrastructure types.

3.8 Small projects

WLC calculations should be carried out for all projects; however, for small projects (GIA of less than 1000m^2, or ten dwellings or fewer) it is allowable to only assess upfront and embodied carbon (modules A1–A5, B1–B5 and C1–C4), with other mechanisms used to reduce operational carbon. In this case, embodied carbon and operational carbon cannot be brought together to understand WLC. Table 3 shows the requirements for most projects versus the requirements for small projects.

	Most projects	Small projects
Upfront embodied carbon (A1–A5)	✓	✓
Lifecycle embodied carbon (A1–A5, B1–B5, C1–C4)	✓	✓
Operational energy (B6)	Predictive energy modelling	Decisions on operational energy come from professional experience and Part L
Operational water (B7)	✓	✓
Whole life carbon (A1–C4)	✓	No WLC comparisons between operational energy and embodied carbon

Table 3: Requirements for most projects versus small projects

3.9 In-use and end-of-life assessments

WLCAs are not just useful for assessing likely impacts at the point at which an asset is designed and delivered; they can also be useful tools in the in-use and end-of-life phases. WLCAs should be undertaken during the in-use phase and before the end-of-life phase, as described in Table 4.

Project phases after completion	Approach to WLCA
In-use phase (in-use carbon measured and reported annually)	B1–B5, B6, B7 and B8 calculated using actual data. B5 updated with a full WLCA when a retrofit/refurbishment occurs. Further life cycle stage predictions updated where required.
End-of-life phase	Modules C1–C4 and D1 should be assessed using an end-of-life forecast before deconstruction or demolition of the existing asset, in order to optimise recovery. An as-deconstructed assessment should be reported.

Table 4: Approach to WLCA after project completion

During the in-use phase, the forecasts for refrigerant leakage, maintenance, repair and replacements, as well as for the operation of the asset, that are included in the post-completion assessment should be checked annually for accuracy against actual impacts. This information can be useful for informing future WLCAs of similar project types.

If retrofitting/refurbishment of an asset with an existing WLCA is considered, a new WLCA should be undertaken to understand the WLC for the retrofitting/refurbishing of the asset and better inform the decision-making process. This can then be integrated into the original WLCA to update it. The original module B5 will be replaced with a full WLCA for the new retrofit/refurbishment scope, with modules B, C and D for the entire scheme updated as necessary; see section 5.2.5.

Before the deconstruction or demolition of any asset is considered, the potential for retrofitting/refurbishment (including extension) should be assessed, for example through a pre-redevelopment audit.

If deconstruction or demolition is required and cannot be avoided, an end-of-life phase WLCA should be used to optimise the recovery of materials from the asset. An as-deconstructed assessment should be undertaken to understand the actual impact of the asset's end of life.

4 Framework for conducting WLCAs

The modular structure described in section 2.1 identifies the life cycle stages; this section provides the overall supporting framework for undertaking WLCAs. The following aspects of WLCAs for buildings or infrastructure assets are defined in the sections shown in brackets:

- the scope of the life cycle stages to be included in a WLCA (4.1)
- the assessment period for a WLCA – the RSP (4.2)
- the scope of the site to be included (spatial boundary; 4.3), and
- the scope of the asset elements to be included (element categories and cut-off; 4.4).

A WLCA also requires the following data, which is described in this section:

- the quantification of the materials used to construct the asset (4.5)
- the development of scenarios for the transportation, installation, maintenance, use, deconstruction and waste treatment of the asset (4.6), and
- carbon data for products and processes across the life cycle (4.7, 4.8, 4.9).

This section also includes discussion of the following considerations:

- addressing uncertainty (4.10) and
- factors influencing the assessment, such as biogenic carbon, carbonation, grid decarbonisation, embodied carbon decarbonisation, carbon offsets, and temporary and permanent carbon storage (4.11).

4.1 The scope of the life cycle stages to be included in a WLCA

A complete WLCA undertaken in compliance with this standard must account for carbon removals and emissions arising over the entire life cycle of a built asset (modules A–C). It must also separately account for the loads and benefits beyond the system boundary considered in module D.

An exception is made for small projects, where predictive energy modelling is not mandatory but is recommended, and which may therefore exclude module B6 and operational carbon from any assessment; see section 3.8.

4.2 The assessment period for a WLCA – the RSP

This section explains the RSP to be used for WLCAs in order to assess the in-use phase (B1–B8), based on the principles outlined in EN 15978 and EN 17472.

RSPs are intended to:

- stretch across a reasonably predictable time period into the future
- allow for a sufficient period of time for the asset to undergo wear and tear – specifically the replacement cycles of major components and systems
- allow for the deconstruction/demolition and disposal of the asset, even if the required service life is longer than the RSP
- enable comparability in the reporting of similar asset types, and
- recognise that decarbonisation trajectories are expected to reduce impacts over time for any type of project.

The RSPs that must be used for compliant WLCAs are as follows.

- **Domestic projects: 60 years.** A 120-year assessment of the envelope should also be undertaken to understand longer-term performance.
- **Non-domestic projects: 60 years.**
- **Infrastructure assets/civil engineering works, other than mines and quarries, and offshore structures related to resource extraction: 120 years (based on guidance in EN 17472:2022).**
- **Mines, quarries and offshore structures related to resource extraction: expected facility operation to extract the resource or 120 years, whichever is shorter.**
- **Standalone fit-out, or enabling or temporary projects: 20 and 60 years with reasonable replacement, repair and maintenance scenarios.**

Note that these RSPs do not set a limit on the life expectancy of a project; RSPs are fixed as described here simply to enable comparability between WLCAs for different projects. They are not intended to reflect the actual desired lifespan or expected service life for an asset, as longevity and retention are usually preferable for overall reductions in life cycle carbon impacts.

When the RSP is longer than the required service life (design life) of a project as specified in the brief, reasonable project-specific scenarios for extended maintenance, repair, replacement and refurbishment (B1–B5) must be developed to cover the period until the end of the RSP. For short life or temporary projects, the assessment must use the relevant RSP, but repeated deconstruction and reuse of the asset or its components could be modelled rather than maintaining the asset over the RSP.

When the RSP is shorter than the required service life, the project must be assessed for the duration of the RSP on a cradle-to-grave basis, i.e. covering all modules A–C (plus module D reported separately). This allows for a sensible and comparable end-of-life scenario, even though the project is expected to have a further service life beyond the RSP.

In addition to using the mandatory RSP, WLC can also be reported against the required service life as additional information. Alternative RSPs may be determined in the project brief or by a specific body commissioning the assessment, but it is important to report these in addition to the mandatory RSP for comparability.

For standalone fit-out projects where the shell and core are not affected, it may be helpful for assessments to be made using a 10-year RSP to highlight the waste that can be associated with typical short fit-out cycles, and to show the benefits of more sustainable fit-out strategies.

4.3 The scope of the site to be included in a WLCA

A WLCA should consider all construction works relating to the project, including any demolition or deconstruction, facilitating works and site preparation required for building the asset, and external works within the site boundary. The site boundary should be in line with the intended use of the built asset, including all areas associated with the project that are integral to its operations. A town planning red line can serve as the site boundary where appropriate.

For projects such as housing or mixed-use schemes, the WLCA also includes external works that are within the site boundary, for example the internal road network, local drainage, street lighting, landscaping and tree planting, and upfront carbon related to external works required outside the site boundary, such as improvements to or links to existing infrastructure.

For fit-out projects, including where appropriate for Cat A and Cat B fit-out scopes, the boundary would be the tenant demise as defined in the lease agreement, plus upfront carbon for any changes required to centralised/communal/shared plant/servicing.

4.4 Element categories

This section sets out the building and infrastructure elements to be included in a WLCA.

4.4.1 Element categories for building assessments

All buildings are made up of building elements, which can be grouped into categories such as foundations, superstructure, envelope and services. The accompanying Building element categories document outlines the building elements that should be covered in a WLCA to ensure consistency of reporting.

All building elements set out in the Building element categories document that are within the scope of a building project, or within the scope of an infrastructure project that includes buildings, and all associated construction works must be included in any compliant WLCA, whatever the project phase.

The elemental breakdown structure to be used for WLCA reporting is derived from RICS' New rules of measurement (NRM).

The granularity of reporting will increase as the design develops, with the maximum level of detail being reported following practical completion of the asset. Increasing availability and maturity of information is expected to contribute to higher accuracy in the WLCA calculations but not result in any change in scope – unless the client brief changes, in which case earlier assessments will act as baselines for later ones that reflect any such changes.

For example, it is usual to include a high-level assumption for the mechanical, electrical and plumbing/public health (MEP) allowances or internal assemblies and finishes during the concept design phase, which are then refined as the project progresses. Refer to section 4.5 for guidance on establishing material quantities at early design stages. If reporting can be done at a more granular level earlier in the design or delivery of the project than indicated in the Building element categories spreadsheet, that should be encouraged.

Reporting template – buildings provides the requirements for a minimum level of reporting granularity at key project milestones. It is recommended that project documentation sets (including modelling protocols) are put in place from the early design stages to facilitate streamlined reporting at the most detailed level of granularity at the later stages of design.

Appendix E **contains colour-coded diagrams showing how to allocate certain elements for consistent measuring, which must be followed.**

4.4.2 Element categories for infrastructure assets and civil engineering works

Large infrastructure or masterplan projects may consist of various sub-projects/assets. These sub-projects/assets should be assessed individually and added together in the WLCA for the entire project. For example, a railway project may include different constituent sub-projects/assets such as tunnels, tracks, bridges and station buildings (see Appendix D).

A detailed elemental breakdown structure for infrastructure assets/civil engineering works is set out in Appendix C, based on the ICMS 3 group breakdown, but a high-level list of the element categories is provided in Table 5.

All element categories set out in Appendix C **that are within the scope of an infrastructure project or a building project that includes infrastructure must be included in any compliant WLCA, whatever the project phase.**

01 Demolition, site preparation and formation
02 Substructure
03 Structure
04 Non-structural works
05 Services and equipment
06 Surface and underground drainage
07 External and ancillary works
08 Preliminaries/constructors’ site overheads/temporary works
12 Production and loose furniture, fittings and equipment

Table 5: Main element categories for infrastructure/civil engineering works based on ICMS 3

As with buildings, information on the constituent elements of infrastructure assets is expected to become more granular over the project duration. However, the scope should remain the same throughout a project's design, construction and life cycle to ensure comparability between the initial baseline assessment and subsequent WLCAs, in order to robustly monitor progress over time. The scope of progressive WLCAs for the same project should only change to reflect changes in the actual scope of works, such as where additional structures are required that were not included in the original brief.

4.5 Material quantities

This section specifies how the quantities of the materials and/or products that make up the components, elements and overall assets need to be determined, in order to be included in the WLCA. For quantification and assumptions related to operational carbon, refer to sections 5.3 and 5.4, and Appendix G.

A compliant WLCA must cover all items listed in the project's bill of quantities (BoQ), cost plan and quantity take-offs (QTOs), or as identified in other records (3D/BIM models, drawings, specifications, etc.). Material quantities from the sources listed in Table 6 must be used for each phase, and their source clearly stated in the WLCA.

Project phase	Material quantity source
Early design phase – predicted or estimated quantities	• Estimation from drawings and 3D models/BIM • QTOs from 3D/BIM/BoQs/cost plan, where available • Industry guidance (see 4.5.1) • Assumptions from other buildings (see 4.5.2) • For MEP, see also Appendix F
Technical design and construction phases – measured or calculated quantities	• QTOs from 3D/BIM/BoQs/cost plan • BIM model and drawings data • Project technical information: specifications, construction methodologies, etc. • Industry guidance (see 4.5.1)
Post-completion phase – actual quantities	• As-built BIM model • As-built cost record of material quantities procured • Cross-reference with as-built records where practical, including material delivery records, concrete pours, etc.

Table 6: Sources of material quantities to be used for WLCAs at each phase

Other project documents or reasonable assumptions may be used where necessary detail is not provided. Appendix M provides guidance on assessing quantities when using 3D/BIM models.

The WLC assessor is expected to review the documentation with the design team for completeness.

For new construction, the assessment should account for gross material quantities. The impacts of the net quantity of material incorporated into the asset should be considered in modules A1–A3. The impact of the amount of any losses during transportation and waste from on-site construction processes should be considered in A5.3.

The measurement system used should preferably be to a recognised current standard, such as NRM for buildings, CESMM4 for civil engineering works or equivalent, in order to enable integration and interoperability with other relevant disciplines, including cost consultants, estimators and quantity surveyors.

In cases of uncertainty regarding the quantities in the cost plan or BoQ, contact the cost consultant to provide relevant clarifications and/or reasonable assumptions in line with the cost model. Any assumptions made should be explicitly stated in the WLCA report.

4.5.1 Using industry guidance

In some cases, industry has produced guidance that provides reasonable assumptions for calculating both material quantities and embodied carbon.

MEP systems can represent a large portion of embodied carbon in a built asset, but are too often ignored or underestimated because of lack of knowledge and data. Throughout this standard, there are references to CIBSE TM65, as it provides a methodology to assess the embodied carbon of building services equipment when no EPDs are available. Refer to Appendix F to find out more about CIBSE TM65 and for further guidance on quantity measurement throughout the design phases.

Other relevant guidance may provide quantification rules of thumb for particular types of elements. For example, CWCT’s guide How to calculate the embodied carbon of facades may be useful for offsite construction, and IstructE’s guide How to calculate embodied carbon can be used for structures. Assumptions taken from industry guidance should be clearly stated in the assessment report.

4.5.2 Assumptions for assessments during early design phases

During the strategic design and concept design phases, where detailed data is not available for certain elements, assumptions can be made using the methods outlined in this section. Method 1 is appropriate for masterplans or for large infrastructure projects. Method 2 is appropriate for the assessment of a building.

These methods do not quantify the materials but provide the embodied carbon data for the asset or element.

Any assumptions made should use appropriate references and consider the scope of the data (system boundaries, geographical location for data and RSP), and should be explicitly stated in the WLCA report, with a commentary provided on any references used.

Care should be taken to identify the use of contingency and uncertainty factors in the data, so that these factors are not duplicated at both element and asset level (see section 4.10).

Method 1: using asset-level benchmarks per square metre of floor area

1. Source the benchmark impact per m^2 GIA of the asset that is being calculated ($kgCO_2e/m^2$ GIA) from the Built Environment Carbon Database (BECD). If BECD benchmarks are not available – or not geographically relevant – the impact per m^2 GIA for a similar asset can be used as a proxy.
2. Work out the carbon impact of the asset separately for each module by multiplying the benchmark impact by the floor area of the asset (GIA).

For infrastructure assets, a similar process using relevant normalisation data could be used if benchmarks are available, for example per km of track or per km of tunnel for railways.

Method 2: using per-element benchmarks per square metre of floor area

1. Source the benchmark impact per m^2 GIA of the element that is being calculated ($kgCO_2e/m^2$ GIA) from the BECD. If BECD benchmarks are not available – or not geographically relevant – the impact of the element per m^2 GIA for a similar asset can be used as a proxy.
2. Work out the carbon impact of that element separately for each module by multiplying the benchmark impact by the floor area of the asset (GIA).

4.5.3 Measuring existing assets that are being retained

In the case of existing assets that are being retained, for example in a refurbishment that is being assessed, where possible actual as-built quantities should be obtained from suitable records such as as-built BIM models and/or drawings. If this is not possible, site surveys may be required. These quantities are not required to determine impact in modules A1–A5, but they are required to assess the impact over the rest of the life cycle.

For existing assets on site that are retained, their ongoing maintenance, repair and replacement over the life of the asset must be reported in modules B1–B4, their impact at the end of life in C1–C4, and any potential benefits and loads from their recovery at end of life in D1.

4.5.4 Measuring existing assets that are being demolished/deconstructed

In the case of existing assets on site that are being demolished/deconstructed, the quantity of material should be obtained from suitable records such as demolition audits or drawings, and after demolition/deconstruction from records of waste generated.

The demolition, waste processing and transport of any material from the demolition/ deconstruction of the existing asset that is required to facilitate new works, or as part of a retrofit/refurbishment, must be reported in sub-module A5.1.

4.5.5 The quality of quantity data used for materials

A **quantities uncertainty factor** provides an indication of the uncertainty associated with the quantities used in the assessment for key products (the most impactful products and materials used), and is used to determine the **WLCA uncertainty factor**. The method for determining the quantities uncertainty factor is described in section 4.10.

4.6 Scenarios

WLCAs generally predict impacts that will occur in the future. For example, during the early design phase, predictions of the materials used, construction impacts and operation of the asset will be made. As the project progresses, some of these predictions can be superseded by more informed calculations or actual data; for example, the actual products that have been used, how they were transported to site and their construction impacts can be used for a post-completion assessment.

The predictions in a WLCA are called **scenarios** and, according to the CEN/TC350 standards, have to be realistic and based on current practice. Therefore, when products are replaced over the life of the asset, the replacement is assumed to be 'like for like', using the same product with the same performance as the product that was originally installed. The end of life of the asset is modelled on what would be expected to happen if the asset was demolished or deconstructed today, rather than what we might predict would happen in the future.

Therefore, reasonable scenarios based on typical practice should be used for the WLCA in the early design phase. These become more specific as the project progresses, with actual data for the construction phase being used for post-completion assessments. This is shown in Table 7.

Project phase	A1–A5	B1–B8	C1–C4	D
Early design phase	Prediction of scenarios based on default specifications or generic data.			
Technical design and construction phases	Prediction of scenarios based on specific data as products are specified and purchased.			
Post-completion phase	Not scenario-based; as-built data used, including actual transport, on-site waste quantities, waste transportation and waste treatment.	Prediction of scenarios based on specific as-built data.		

Table 7: Scenario data for each project phase

In this subsection, default scenarios for the UK are provided to ensure consistency of assessment, rather than each project making their own estimates of current practice. The scenarios in other geographical regions may vary significantly due to different supply chains, construction practices and end-of-life practices.

4.6.1 Scenarios for A4–A5 during the early design phase

During the early design phase, scenario data for A4 (transport to site) should be based on the estimated quantity of material and the default distances provided in Table 17, or the data from a collective EPD. See section 5.1.3 for more details. National trade associations may also provide data on typical transport distances outside of EPDs.

For A5, default wastage figures should be used with estimated quantities and default end-of-life routes to account for site waste, and default energy consumption on site should be used. See section 5.1.4 for more detail. These defaults are UK-specific and should be reviewed for projects outside the UK, where collective EPDs or CEN c-PCR may provide guidance.

4.6.2 Scenarios for A4–A5 during the technical design and construction phases

During the technical design and construction phases, for A4 the measured quantity and actual distance from the chosen supplier to the site and any return journey should be used. Similarly, for A5 measured quantities and specific data for wastage and end-of-life routes should be used if available, with default data for energy consumption on site; see section 5.1.4.

4.6.3 Scenarios for A4–A5 for post-completion assessments

For post-completion assessments, A4 transport should be modelled based on the actual quantities used, the actual distance from the supplier, vehicle loading, empty return and fuel consumption data, if known. Site wastage in A5 should be based on the actual quantities of different types of waste (e.g. metals, timber, inert material) and their end-of-life routes as provided by waste contractors, and actual energy and water consumption on site should be used.

4.6.4 Scenarios for replacement in B4 in all project phases

As part of the scenarios for an asset, a prediction of the service lives for materials and components needs to be made so that any replacement over the RSP can be calculated and reported in B4. In practice, service lives may vary due to factors such as the quality of installation, maintenance, usage and exposure, which should be considered. Default lifespans are provided in Table 20, which should be used for the UK in the absence of more specific data. Reference service lives may vary considerably in different climates, so it is advisable to consider geographically relevant default lifespans for assessments in regions outside the UK.

4.6.5 Scenarios for B1–B8, C1–C4 and D in all project phases

For modules B1–B8, C1–C4 and D, the default scenarios (e.g. end-of-life routes) provided in section 5 should be used for all assessments in the UK. For projects outside the UK, they should be reviewed if current practice differs.

During the concept design phase, quantities should be predictions based on estimated quantities and generic data (e.g. typical emissions from recovery). Then they should be predictions based on measured quantities and specific data, where available, until post-completion where they should be predictions based on the as-built quantities and specific data for post-completion assessments. See sections 5.2–5.7 for more detail.

4.7 Carbon data sources for the product stage (A1–A3)

This section explains the types of carbon data that should be used in a WLCA for modules A1–A3, which varies according to the project phase.

The BECD has been developed to provide an up-to-date list of generic and specific carbon data for the UK, including environmental product declarations (EPDs). For the UK, the BECD should be used as a first point of reference to identify carbon data for construction materials and products. See Appendix B for more detailed information on the various types and sources of carbon data.

Any EPD should be independently verified according to ISO 14025, with third-party verification preferred. EPDs using EN 15804 and ISO 21930:2017 are preferred. EPDs using EN 50693 may be appropriate for electrical equipment.

The WLC assessor must explicitly state the data source in the WLCA report, and for generic data the territorial scope and basis (consumption- or production-based) for the various types of carbon data used in the WLCA.

A **carbon data confidence factor** based on **carbon data confidence scores** for the carbon data used for key products (the most impactful products and materials used) provides an indication of the uncertainty associated with the choice of data used for the assessment. The method for calculating the carbon data confidence scores, and therefore the carbon data confidence factor, is described in section 4.10, including mandatory requirements for reporting.

Table 8 shows the types of carbon data that are most suitable at different project phases.

Project phase	Carbon data for A1–A3
Early design phase	• Generic carbon factors. • Appropriate national carbon factors from accepted industry databases.
Technical design and construction phases	• Specific carbon factors from EPDs where products/systems are specified or purchased during construction phase. • If EPDs are not available, use generic carbon factors (appropriate national carbon factors from accepted industry databases).
Post-completion phase	• Specific carbon factors from EPDs for the actual products/ systems used. • If EPDs are not available, use generic carbon factors (appropriate national carbon factors from accepted industry databases).

Table 8: Types of carbon data to be used for the product stage during different project phases

4.7.1 Carbon data sources in the early design phase

During the strategic and concept design phases, where usually a particular manufacturer's products will not have been chosen (and often even the materials to be used are not definite), generic data is the preferred data type to use. Generic data is not manufacturer-specific and should be chosen as typical of the type of component, product and/or material to be used. See section 4.5.2 for the use of embodied carbon benchmark data for assessments during early design phases.

4.7.2 Carbon data sources in the technical design, construction and post-completion phases

As the project progresses, and once materials (but not a particular manufacturer) have been chosen, the most representative type of generic data for a material or product would be a collective EPD from all the members of the appropriate regional industrial sector. For example, in the UK this would be based on data from all members of a UK trade association, followed by a collective EPD based on a representative selection of sites/producers. Where a product is commonly imported, it may be relevant to look to a collective EPD with a wider geographical basis, such as European production, or an EPD that is based on average consumption in a region rather than average production in a region. Collective EPDs also often represent the average of a group of products or a representative product, rather than one specific product.

Collective EPDs, whether sector average, product-specific or representative, should describe what they represent and provide information on the variation of impact across the range of products if this is significant (normally considered to be more than ±10%). If a collective EPD is not available, generic data from a geographically relevant database would be appropriate. The BECD is intended to be a source of generic data for the UK. See Appendix B for more information about sources of data.

If no average or collective EPDs or generic data are available, a specific EPD from the region could be used as a proxy for a generic product, but this will affect the data confidence scores in terms of technological representativity. Data from a different region, for example a collective EPD, generic data or a specific EPD, could also be used as a proxy for manufacturer data, but this will reduce the data confidence score in terms of both geographical and technological representativity.

4.7.3 Carbon data for MEP products

For MEP products in early design phases, when no generic EPDs are available, generic datapoints with the highest confidence level possible should be created using the CIBSE TM65 generic embodied carbon methodology. The CIBSE MEP product-level database may provide these values for some MEP products.

In later design phases, where EPDs for specific products are available, they should be independently verified according to ISO 14025, with third-party verification preferred. EPDs using EN 15804 and ISO 21930:2017 are preferred; EPDs using EN 50693 (for electrical equipment) and ISO 14025 can also be used.

For MEP products where no specific EPDs are available, the CIBSE TM65 method should be used, with assumptions from local TM65 addenda if the product is installed outside the UK. Mid-level calculations should be favoured over calculation using the basic methodology.

For conversion of operational energy into carbon, see section 4.9.

4.8 Carbon data for scenarios (pre-construction stage, construction stage, in-use stage and end-of-life stage)

The impact of scenarios once the product has left the manufacturer's premises is a combination of the scenario chosen and the carbon impact of the relevant processes.

During the early design phase, carbon data for transport (A4 and C2), and energy and water use during construction (A5), should be based on the most recent GHG conversion factors for company reporting, as issued by the relevant designated bodies (e.g. the Department for Energy Security and Net Zero in the UK) or on data from generic EPDs. Outside the UK, the Global Logistics Emissions Council Framework for Logistics Emissions Accounting and Reporting may provide useful data.

During later project phases, data from specific EPDs should be used if available and relevant to the project.

EPDs chosen to provide product-level data may provide carbon impact data for modelled scenarios, but this may not reflect the default scenarios required for asset-level assessment. Here are some examples.

- An EPD may provide the impact for module A4 based on a typical freight transport of 50km by road, but the product may need to come 75km by road to the site. In this case, the EPD data for A4 should be adjusted by 150% to reflect the project-specific 75km distance.
- An EPD may provide the impact for A4 based on a typical freight transport of 100km by road, but the product may need to come to the UK by a combination of road and container shipping, and the EPD data cannot be used to model shipping.
- An EPD may provide impact for modules C3 and D based on 100% energy recovery in Germany, but the default scenario would be 55% recycling and 45% incineration in the UK. The EPD data cannot be used to model recycling and incineration in the UK.

If the impact data for a scenario in a specific EPD cannot be used directly or adjusted, generic EPDs or data should be used instead. Generic EPDs and generic databases, discussed in Appendix B, may also provide impact data on typical transport distances, wastage, maintenance and end-of-life routes and impacts, which can be used. The BRE IMPACT database provides typical UK scenario impact data for most construction products, but the data is currently only available in IMPACT-compliant tools.

In the case of refrigerant leakage (modules B1 and C1), the most recently published Intergovernmental Panel on Climate Change (IPCC) figures for the GWP of refrigerants should be used. The values in the CIBSE DT65 Embodied Carbon Calculator are also a good resource.

This standard provides default scenarios, and some impact data and links to data such as recent GHG conversion factors for company reporting, as issued by the relevant designated bodies (e.g. the Department for Energy Security and Net Zero in the UK), which can be used during the early and technical design phases in the absence of more specific data. However, they should be checked to ensure they are relevant to the project location.

4.9 Allowable carbon conversion factors for operation (B6–B7)

The most recent GHG conversion factors for company reporting, as issued by designated bodies (such as the Department for Energy Security and Net Zero in the UK), should be used for calculating the carbon equivalent (CO_2e) impact of modules B6 and B7.

For the emissions associated with energy use (B6), different sets of carbon conversion factors should be used, depending on the project phase and the intent of the assessment (further described in Table 9):

- set 1 for design decision-making
- set 2 for reporting and benchmarking over the RSP, and
- set 3 for annual in-use reporting.

A non-decarbonised and a decarbonised scenario must always be calculated.

Additionally for set 1, in order to understand the WLC consequences of design decisions (e.g. additional insulation or heating system type), a net-zero-grid-compatible scenario can be used to reflect the broader impacts on the wider electricity grid.

Project phase	Values based on	Carbon conversion factor set
Early design	Prediction based on generic values	When making design decisions – understanding trade-offs WLC over the RSP – design decisions (set 1) When reporting WLC – for comparison between projects or benchmarking WLC over the RSP – predictions (set 2)
Technical design and construction	Prediction based on specific values	
In-use	Based on metered consumption	Annual reporting (set 3)
Post-completion	Prediction updated based on as-built values	WLC over the RSP – predictions (set 2)

Table 9: Carbon conversion factor sets by project phase; see Appendix I for a description of sets 1, 2 and 3

More information on what conversion factor to use for energy use (B6) can be found in Appendix I and the Energy – supplementary tables supporting document.

If WLC calculations are developed to understand the WLC consequences of design decisions (e.g. additional insulation or heating system type), the carbon benefit of onsite renewables should not be included, as whether the building does or does not have onsite renewables should not impact building-level trade-offs between operational and embodied carbon. For more details, refer to Appendix H4.1.

The carbon conversion factors used must account for both direct and indirect GHG emissions: scopes 1, 2 and 3, including well-to-tank (WTT) and transmission and distribution (T&D) impacts, and should account for the embodied carbon of energy infrastructure where applicable and available. Figure 10 identifies the stages of carbon conversion factors and where the emissions to be accounted for are specifically produced; see Appendix H for more information.

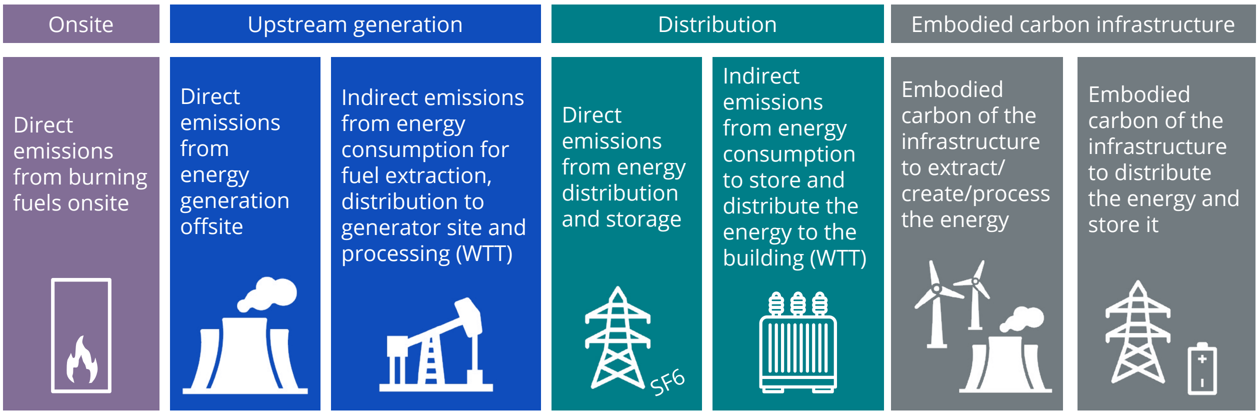


Figure 10: Carbon conversion factor – what is included

More information on what carbon conversion factor set to use for energy use (B6) can be found in Appendix I.

4.10 Addressing uncertainty in WLCAs

When costing projects, it is common for contingencies to be used to reflect uncertainties. For WLCAs there are similar uncertainties, particularly during the early design phase when far less is known about the final design and materials. In this standard, this uncertainty is managed by developing a **WLCA uncertainty factor**, which is made up of three component parts.

1. A **contingency factor**, based on the project phase, is applied at during all project phases to modules A, B, C and D. It reflects uncertainty regarding the design of the asset, its construction and the quantities and types of materials used. It can be assessed for each element as their uncertainties may differ, or default values for the asset overall may be used. Uncertainty generally reduces as the project phases proceed and more is known and finalised.

2 A **carbon data uncertainty factor**, based on the representativeness and quality of the carbon data used for materials. It is added during the detailed design, construction and post-completion phases. It reflects uncertainty regarding the representativeness of the carbon data in relation to the impact of the actual products that will be used, and the quality of the data. It should be high when generic data is used in any phase, and should be low when specific data for the actual products is used. It is calculated using the asset data confidence score, based on the representativeness of ten key datasets.

3 A **quantities uncertainty factor**, based on the expected accuracy of the material quantities data being used in the project. It is also added during the detailed design, construction and post-completion phases, and reflects uncertainty regarding the quantities of the products that will be used. It should be high when estimates or benchmark data are used, and low when measured quantities are used. It is calculated using the quantities uncertainty level for ten key datasets (see section 4.10.3).

How these three component factors are assessed, and how the WLCA uncertainty factor is then calculated from them, is set out in the following subsections.

4.10.1 The contingency factor

The UKGBC's Embodied Carbon: Improving Modelling and Reporting provides useful guidance on aspects that may affect contingency relating to uncertainty. For example, where a project team has already worked on similar buildings, the assessment of WLC for the next project is likely to have less uncertainty than if a team that has not previously worked together undertakes a WLCA for a new and unique project. It is also likely that at a particular phase of the project, some elements may be well developed while others have not been considered. The data used for quantities may also be of different quality; this will affect the level of uncertainty.

To account for uncertainty in this standard, the WLC assessor must consider contingency for the project based on the uncertainty at the time of the assessment. They can use the default contingency factors included in Table 10, which are applicable to all elements and life cycle stages, or such factors can be derived from a more detailed assessment of contingency on an element-by-element basis. The UKGBC suggest an approach using tolerance ranges for carbon results for different elements at different project phases, which could inform this process.

Project phase	Default contingency factor to apply to all life cycle stages and modules
Early design	15%
Technical design and construction	6%
Post-completion	0%

Table 10: Default contingency factors

Although uncertainty regarding the products used should be minimal once they have been installed, even a post-completion-phase WLCA may have uncertainty around some of the quantities used (for example for MEP), which should be reflected in the quantities uncertainty factor used.

In order to account for uncertainty and lack of detailed or complete information, particularly during the early design phases, after assessing and reporting the results for each life cycle information module and element category using Reporting template – buildings or Reporting template – infrastructure, the relevant contingency factor(s) must be applied to all modules A–D before reporting upfront, embodied, operational and user carbon in Reporting template – summary.

If element contingency factors have been used, these should be applied to the element results after initially using Reporting template – buildings or Reporting template – infrastructure, and before reporting upfront, embodied, operational and user carbon.

The contingency factor(s) used must be reported in the WLCA report.

4.10.2 The carbon data uncertainty factor

During early design stages, it is best to use generic data to represent products and materials, as it is generally not clear the exact products that will be used, and from where and which manufacturers they will be sourced. There is therefore considerable uncertainty as to whether the dataset chosen will accurately represent the product that is finally selected, and it is therefore inappropriate to use the carbon data uncertainty factor during the early design phase. As the design progresses, the aim is to use data that most accurately represents the products and materials being used in the asset. At later design stages, this is ideally a specific EPD from the manufacturer for the product being used. However, if this is not available, representative generic data or sometimes even a proxy EPD may have to be used, with varying uncertainty in terms of the representativeness of the data. Different data sources may also have different levels of quality, depending on the type of verification or standards used.

During the detailed design, construction and post-completion phases, these uncertainties around the data used are managed using carbon data confidence scores. This section describes the assessment of carbon data confidence scores, resulting in an asset carbon confidence score, which can be translated into the carbon data uncertainty factor.

The carbon data confidence score approach

Carbon data confidence scores are calculated for each of the **key products** used in the asset.

Key products are identified as the ten most impactful products or materials in terms of the percentage of the asset’s embodied carbon impact (modules A1–A5, B1–B5, C1–C4).

The definition of a key product will vary depending on the granularity of the data used: it could cover a whole facade system if a single EPD has been used to provide data, or it could be just the glass if a single EPD for all the glass has been used. For example, if separate EPDs for different concrete mixes have been used for different concretes, they should be considered as separate products when identifying the key products. If a single generic dataset has been used to represent several different concrete mixes, they would be considered to be a single product.

The **carbon data quality matrix** to be used to assess datasets is provided in Table 11.

	Geographical representativeness (maximum 10 points)		Technological representativeness (maximum 12 points)				Temporal representativeness – assess either as an EPD or generic dataset (maximum 8 points)				Data aspects (maximum 10 points)			
	Geography		Technology		Product specificity		For EPD		For generic datasets		Granularity		Verification	
Very good	Refers to the specific geographic context for large countries, same region (e.g. UK for UK)	10	Reflects identical technology (e.g. BF/BOF steel with similar recycled content)	6	Data for actual product used	6	Year of data collection less than 4 years from year of construction	8	Reference year less than 3 years or published less than 2 years from year of construction	8	Site-specific data (actual factory and manufacturer used)	5	Third-party independently verified to EN 15804 or ISO 21930	5
Good	Refers to a similar geographic context (e.g. UK data for Ireland)	7	Partially reflects the technology and technical characteristics (e.g. BF/BOF steel with different recycled content)	4	Representative or average product adapted by relevant characteristic (e.g. data per m^2 adapted by mass/m^2 or scaling factor provided	5	Year of data collection less than 7 years from year of construction	6	Reference year less than 6 years or published less than 5 years from year of construction	6	Manufacturer specific data (actual manufacturer used and average site or different site)	4	Independently verified to ISO 14025 or EN 50693	4
Fair	Refers to a very different geographic context or much larger region (e.g. Italy for UK, EU for UK)	4	Does not satisfactorily reflect the technology and technical characteristics (e.g. steel generally)	3	Average data/ representative product for product group of actual product used	4	Year of data collection less than 10 years from year of construction	4	Reference year less than 10 years or published less than 10 years from year of construction	4	Regional sector data (e.g. UK or EU)	3	Peer reviewed to ISO 14044	3
Poor	Refers to a totally different context (different continent, e.g. Canada for UK, EU for China)	2	Does not reflect the technology and technical characteristics at all (e.g. EAF steel for BOF steel)	1	Any proxy dataset or data extrapolated from group of datasets	2	Year of data collection less than 15 years or published more than 10 years from year of construction	2	Reference year less than 15 years or published more than 10 years from year of construction	2	Global sector data	2	Not verified or peer reviewed	0
Very poor	No evaluation made	0	No evaluation made	0	No evaluation made	0	Other or no evaluation made	0	No evaluation made	0	Proxy data or no evaluation made	0	No evaluation made	0

Table 11: Carbon data quality matrix used to generate data confidence scores during technical design, construction and post-completion phases; these are assessed for each key product/material and then averaged, weighted by their embodied impact

For each product, the product-stage dataset providing carbon data for A1–A3 should be assessed against each of the criteria for geographical, technological and temporal representativeness, and for the data aspects shown in Table 11. The aim is to identify, for each key product, the level of confidence that the dataset used is completely representative of the carbon impact of the actual product that will be used. The relevant points for each aspect should be added together for each dataset, with a maximum points score of 40 for the least uncertain data (e.g. a recent EN 15804 EPD for the exact product and manufacturer used on the project) and a score of 0 for the least representative data with no verification.

An example of the calculation of carbon data confidence scores for different types of data relative to the product used in an asset is provided in Table B2 in Appendix B, together with more information about the process.

The carbon data confidence scores for all key products are then averaged, weighted by their embodied carbon impact (A1–A5, B1–B5, C1–C4), to give the asset carbon confidence score.

During the detailed design, construction and post-completion phases, the asset carbon confidence score produced using this method must be reported in the WLCA report, together with the percentage of the asset's overall upfront and embodied carbon for which the key products are responsible.

For example, the key products may represent 35% of the asset's upfront carbon and 52% of its embodied carbon, and have a weighted asset carbon confidence score of 30.

Once the confidence score has been determined using Table 11, the corresponding carbon data uncertainty factor percentage can be identified using Table 12. This is then added to the contingency factor explained in section 4.10.1.

Asset carbon confidence score	≤10	10<15	15<20	20<25	25<30	30<35	35<40	40
Carbon data uncertainty factor	7%	6%	5%	4%	3%	2%	1%	0%

Table 12: Carbon data uncertainty factor to be included in the WLCA uncertainty factor

During the detailed design, construction and post-completion phases, the asset carbon confidence score must be translated into the carbon data uncertainty factor, which must then be included in the WLCA report.

In order to account for uncertainty regarding the representativeness of carbon data and its quality, after assessing and reporting the results of each life cycle information module and element category using Reporting template – buildings or Reporting template – infrastructure, the carbon data uncertainty factor must be applied to all modules A–D before reporting upfront, embodied, operational and user carbon using Reporting template – summary.

4.10.3 The quantities uncertainty factor

A quantities uncertainty factor for key products (the most impactful products and materials used) provides an indication of the uncertainty associated with the quantities used for the WLCA.

During the detailed design, construction and post-completion phases, the quantities uncertainty factor must be assessed using the approach set out in this section, and this assessment must be included in the WLCA report.

Using Table 13, the quality of the quantities data must be assessed for each of the key products: the ten products or materials that cause the greatest impact for the asset, as described in section 4.10.2.

Quantities uncertainty levels (QULs)	QUL score	Examples
Very good	0	Actual measured/delivered quantities
Good	1	Design measured/calculated/modelled averages
Fair	3	Estimated building information
Sufficient	5	Benchmark building information

Table 13: Quantities uncertainty levels to be used to assess quantities of key products during the technical design, construction and post-completion phases

The QUL scores for all key products are then averaged, weighted by their embodied carbon impact (A1–A5, B1–B5, C1–C4), to give the asset QUL score.

Once the asset QUL score has been determined, then using Table 14 the corresponding percentage can be identified and added to the contingency factor explained in section 4.10.1 and the carbon data uncertainty score explained in section 4.10.2 to give the WLCA uncertainty factor.

Asset QUL score	<0.5	<1	<2	<3	3–5
Quantities uncertainty factor	0%	1%	2%	3%	4%

Table 14: Quantities uncertainty factor to be included in the WLCA uncertainty factor

In order to account for uncertainty regarding the quantities data, after assessing and reporting results for each life cycle information module and element category using Reporting template – buildings or Reporting template – infrastructure, the quantities uncertainty factor must be applied to all modules A–D before reporting upfront, embodied, operational and user carbon using Reporting template – summary.

4.10.4 The WLCA uncertainty factor

The total percentage figure to be added to the WLCA is therefore a combination of the contingency factor, the carbon data uncertainty factor and the quantities uncertainty factor.

Worked example

The project is at the technical design stage and a full WLCA has been completed.

1. For the figures for modules A, B, C and D, a contingency factor of 6% from Table 11 is identified.
2. The ten most impactful products or materials are identified (see section 4.10.2). Their carbon confidence scores are then assessed using Table 13.
3. Average the scores for the ten most impactful products or materials, weighted by their embodied carbon impact (A1–C4), to give the asset carbon confidence score for the asset.
4. Assuming the asset carbon confidence score is 23, then using Table 12, identify 4% as the corresponding carbon data uncertainty factor.
5. The quantities data for the ten most impactful products or materials is assessed using the quantities uncertainty levels (QULs). Average the QULs, weighted by their embodied carbon impact (A1–C4), to give the asset QUL score.
6. Assuming the asset QUL score is 1.2, then using Table 14, the assessor would identify 1% as the corresponding quantities uncertainty factor.
7. The contingency factor (6%), carbon data uncertainty factor (4%) and quantities uncertainty factor (1%) are then added together to produce the WLCA uncertainty factor (6% + 4% + 1% = 11%).
8. The total combined percentage is then added to the technical design stage WLCA figures reported in Reporting template – buildings. This revised total, accounting for uncertainty, is the figure that should be reported in Reporting template – summary for this project stage.

4.11 Factors influencing the assessment

4.11.1 Biogenic carbon

When any biomass (e.g. timber or agricultural crops) enters the technosphere, any sequestered carbon – the biogenic carbon contained or 'sequestered' within the biomass – must be considered as a removal of biogenic CO_2 from nature into the product system in the module in which it enters the system, but only, in the case of timber, if it has been sustainably sourced.

EN 15804+A2 allows removals of sequestered carbon in timber sourced from short-term forests, degraded forests, managed forest, or forests with short-term or long-term rotations (i.e. not 'native' forest, primary forest, old growth forest or rainforest). However, this standard restricts accounting of removals of sequestered biogenic carbon for timber to only timber that can demonstrate its sustainability, for example through FSC or PEFC certification or equivalent, or to timber that is sourced from countries that account for Article 3.4 of the Kyoto Protocol and report increasing forest carbon pools.

For timber, biobased packaging or timber formwork that is not sustainably sourced, no removal of biogenic carbon must be considered at any point in the life cycle. However, any emission or transfer of sequestered carbon from timber that has not been sustainably sourced must be considered as an emission of carbon arising from land use and land use change (LULUC), considered in the same way as a fossil carbon emission.

This means these products will have no removal of biogenic carbon in A1–A3 but will have an impact from the emission or transfer to nature, or transfer to the next product system, of sequestered carbon at end of life. This means they will have a net emission of this carbon, in addition to the emission of carbon from other processes such as extraction, transportation and processing.

To be compliant with this standard, biogenic carbon must be reported as described in the reporting templates. Section 6 details the reporting requirements.

For sustainably sourced timber and other biomass, the point at which biogenic carbon enters the product system boundary is taken to be the point of harvest. Appendix N provides a detailed description of how to quantify the amount of biogenic carbon sequestered in products within a building or infrastructure asset.

The sequestered biogenic carbon in sustainably sourced timber and other biomass must be considered to leave the product system boundary when it is either:

- **transferred to another product system through reuse, recycling or recovery as a secondary fuel**
- **transferred to nature when emitted (as CO_2 or methane) through combustion (either incineration or energy recovery processes), degradation in landfill, or emission from anaerobic digestion or composting, or**
- **transferred to nature if it remains undegraded in landfill after 100 years.**

In each case, this must be considered as an emission of biogenic carbon (as CO_2 or methane as appropriate) in the module in which it leaves the system.

To calculate impact, removals of biogenic CO_2 have a GWP of –1 $kgCO_2e$ per kg of CO_2 removed; emissions of biogenic CO_2 have a GWP of +1 $kgCO_2e$ per kg of CO_2 emitted. This is the same approach that is used in EN 15804, EN 16485, ISO 14067, PAS 2050 and the GHG protocol. Emissions of biogenic methane (e.g. from the escape of landfill gas) have a GWP of 27 $kgCO_2$ per kg of methane, because methane is a stronger greenhouse gas than CO_2.

If correctly assessed – accounting correctly for all the co-products, waste and combustion of biomass during the production of sustainably sourced timber and other biomass – the sequestered biogenic carbon contained in products and their packaging should be reported as a removal of biogenic CO_2 in A1–A3 (i.e. a negative emission of CO_2), as an emission of biogenic CO_2 for any packaging disposed of in A5, and as an emission of biogenic CO_2 in C3 or C4 for the product at end of life. Sustainably sourced biobased product wastage in A5, and any replacement of sustainably sourced biobased products or packaging in B2–B4, will have balanced removals and emissions of biogenic carbon in each module, unless methane is emitted during disposal.

In module B5, if more sustainably sourced timber or biomass is added to the asset during planned retrofit/refurbishment or change of performance, there will be a net removal of biogenic carbon in B5, balanced by an emission in C3/C4. If sustainably sourced timber or biomass is removed from the asset overall during the planned change in performance, there will be a net emission of biogenic carbon in B5, balanced by a removal in A3.

As sustainably sourced biobased packaging and timber formwork reach their end of life during the construction stage, emissions and transfers in A5 should balance removals in A1–A3 and A5 respectively for these items. Therefore, the sum of all biogenic carbon removals and emissions over A1–A5 should equal the sequestered biogenic carbon stored in products installed in the asset in A1–A3. Appendix N provides more detail on how to calculate the sequestered biogenic carbon stored in the asset and LULUC carbon, using information from EPDs or other data sources.

Because there should be a biogenic carbon balance over modules A–C, it makes little difference whether biogenic carbon is included in targets for embodied and whole life carbon, as the removals of biogenic carbon in modules A1–A3 are balanced by emissions in modules C3 and C4.

However, when assessing modules A1–A3, the result can potentially reduce as more biomass is used because of the increasing quantity of biogenic carbon sequestered in the asset. This could lead to perverse incentives, such as where additional biomass is included in a building purely to reduce carbon impacts in A1–A5. Although timber and biomass are renewable, we need to recognise that they are still limited resources that can be easily depleted, so we should only use what we need to efficiently deliver the required function, even though there are benefits to long-term storage of biogenic carbon discussed in Appendix N. In doing so, we ensure that the maximum number of assets can benefit from biogenic carbon storage, without depleting a valuable resource for future generations.

Biogenic carbon removals and emissions from modules A1–A3 (the sequestered biogenic carbon within products) must not be included in the calculation of upfront carbon, but must be reported separately as the sequestered biogenic carbon stored within the asset in A1–A3. Any LULUC carbon emissions in A1–A5 must be considered as a fossil carbon emission, and included with other fossil carbon emissions and removals in A1–A5 in the calculation of upfront carbon. See the reporting templates and Appendix N for more information.

Biogenic carbon and LULUC carbon must be included with fossil carbon in the calculation of both embodied carbon and WLC.

Biogenic carbon and LULUC carbon must not be decarbonised. See section 4.11.5.

For timber or other biobased materials (biogenic carbon) that is modelled as reused or recycled at the end of life, the biogenic carbon sequestered within it should be taken into account as a transfer (emission) from C3. For any net output of biomass into module D, the transferred biogenic carbon should be treated as a removal (a negative emission). Any biogenic carbon sequestered in the substituted product or material in D1 should also be considered in D1. Deducting the impact of the substituted product involves deducting the removal of sequestered carbon in the substituted product, so it will be equivalent to adding it as an emission in D1. If the quantity of sequestered carbon in the recovered and substitute products are the same, this will result in a biogenic carbon balance. An example is provided in Appendix K.

Special care needs to be taken regarding timber formwork, which has a particularly short service life and leaves the system even before practical completion – effectively still at the construction stage (A5). To ensure a fair approach regarding timber formwork and avoid misleading results, the following simplified assumption should be made in a WLCA.

A plausible scenario for the end of life of the timber formwork should be worked out by liaising with the design team and project contractor. If the formwork has only been used on this project (most likely) and is either recovered or disposed of after use, the associated impact of production, waste treatment and disposal can be reported in module A5. If the formwork is expected to be reused on several projects (less likely), to avoid shifting the end-of-life impacts to the last project it is being used in (given that each use is responsible for major degradation of the formwork), its production and the end-of-life impact (A5) according to the expected scenario should be divided by the number of expected reuses. The resulting figure should be included in the assessment in A5. If the formwork is made from sustainably sourced timber, biogenic carbon removals and emissions/transfers should balance, so no biogenic carbon impact will be reported in A5. If it is made from timber that has not been sustainably sourced, emissions from the end of life of any sequestered carbon will be considered as LULUC carbon in A5 and reported as a fossil emission.

In the absence of more specific information, timber formwork should be assumed to be used a total of three times and incinerated at the end of its life.

4.11.2 Carbonation of CaO and $Ca(OH)_2$

Building elements containing cementitious materials and/or lime, such as concrete and mortar, have the potential to absorb CO_2 when their surfaces are exposed to the air as the contained calcium oxide (CaO) and calcium hydroxide ($Ca(OH)_2$) react with CO_2 in the atmosphere. This natural process is called carbonation but can occur very slowly or quickly, depending on the situation.

Concrete contains calcium hydrated oxides and therefore undergoes carbonation when exposed to oxygen. However, carbonation beyond a certain level is not desirable in reinforced concrete as it may cause corrosion of the embedded steel bars.

It is therefore deliberately limited by appropriate mix design and reinforcement cover allowances (EN 1992-1-1; BS 8500).

The carbonation process occurs over the life of concrete and lime-based elements, and should therefore be accounted for in the reporting of module A (for example for lime-based elements, which can carbonate rapidly), in-use (B1; see section 5.2.1) and end-of-life (C; see section 5.6) stages, where applicable. Carbonation may also occur in module D, but only if recycled concrete aggregate is commonly stockpiled for long periods before use. Detailed guidance on calculating and reporting the carbon uptake from carbonation is given in EN 16757.

Carbonation rates depend on the duration of exposure, concrete designation and exposure conditions, including any concrete surface treatments which will most likely limit carbonation. **The exposure of elements (for example whether sheltered or exposed if external, or if internal whether limited by paint, wallpaper or floor coverings) must therefore be considered if calculating the rate and degree of carbonation using the information provided in EN 16757.** The degree of carbonation shows the maximum CO_2 absorption capacity associated with any given quantity of cementitious material; once this is reached, no further carbonation can take place.

Measured data often shows lower carbonation in practice than suggested by theoretical measurements. Data from EPDs or equivalent sources can be used to account for the impact of carbonation in modules A1–A3, A5, B1 and C3/C4, provided that the conditions in the scenario selected in the data source coincide with the anticipated project-specific ones, particularly in relation to exposure. If the assumptions are either not sufficiently transparent or diverge from what is expected to apply to the specific project being assessed, carbonation figures should either not be taken into account or adjusted accordingly.

Removals from carbonation cannot be decarbonised.

4.11.3 Energy modelling

This standard has brought in a more detailed methodology for predictive energy modelling relating to module B6 than the previous edition, with WLC assessors no longer able to use Part L 2021 calculations for B6.

Embodied carbon and operational energy can be assessed separately. However, when they are brought together to optimise whole life carbon, predictive energy modelling must be carried out, as described in section 5.3 relating to module B6.

Where predictive energy modelling is not available, compliant upfront carbon and embodied carbon assessments can still be carried out as these assessments do not include B6, but WLC cannot be assessed through this method (see sections 3.8 and 4.1).

4.11.4 Future energy projections: grid decarbonisation in modules B6, B7, B8 and D2

Depending on the purpose of the assessment and the corresponding carbon conversion factor set used, it is important to consider grid decarbonisation as an additional part of the WLCA. Decarbonised emission factor projections published by central governments or designated bodies should be used. If there is a range of scenarios, the most conservative scenario should be used.

In the UK, the Future Energy Scenarios (FES) falling short scenario (excluding negative emissions from bioenergy with carbon capture and storage (BECCS), even though this is not a requirement of EN 15978:2011 or EN 15804), from the most recent FES developed by National Grid, should be used. For more details, see Appendix G. Similar scenarios produced by central governments and designated bodies should be used for different countries, and assessors should clearly identify and explain the decarbonisation scenarios used. Where decarbonisation scenarios do not exist in the country of the assessment, follow the guidance in Appendix G, where more information on how to account for electricity grid decarbonisation for module B6 can be found.

The benefit of energy and other utilities exported from the asset over its life cycle will be expected to reduce as these utilities decarbonise, as well as any user activities in B8 and the benefits of any utilities exported from the asset over the RSP in D2.

Decarbonisation of the electricity grid will similarly affect the carbon emissions factors associated with water usage and treatment reported in module B7. Where decarbonisation scenarios for B7 are not available, the same decarbonisation rate that is used in B6 should be used, similar to the upstream B6 emissions rate; see Appendix G4.

For future energy projections, results both with and without grid decarbonisation must always be reported, clearly stating the grid decarbonisation source used.

4.11.5 Material decarbonisation

Alongside grid decarbonisation, it is expected that extraction, transportation and manufacturing processes will also decarbonise, so it is important to consider their decarbonisation as an additional part of the WLCA. Although there has already been some evidence of the decarbonisation of construction material production, it has been limited and much of it has been attributable to the decarbonisation of the grid. In 2015, the UK government published Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 for several sectors producing construction materials. A number of sectors, both in the UK and internationally, have also produced net zero carbon roadmaps. These roadmaps include decarbonisation scenarios that vary in their optimism, but all rely on the development and implementation of new technologies, such as the use of carbon capture and storage, which have not yet been proven at scale. Many also rely on sufficiency strategies, such as building less and refurbishing more, and material efficiency strategies, which will not reduce the carbon intensity of material production or influence the 'like-for-like' replacements that are required in EN 15978 and EN 17472, and therefore in this standard.

The transfer or emission of biogenic or LULUC carbon at the end of life of biobased material, and the emission of fossil carbon at end of life from incineration or energy recovery (for example from fossil plastics), are a function of their carbon content. This cannot be decarbonised except through the use of carbon capture, usage and storage (CCUS), which cannot be considered as part of the calculation of impact. Similarly, in-use stage emissions from, and removals by, materials in sub-module B1.1 cannot be decarbonised, as they are a function of the original materials installed and not subject to change over time. However, it is assumed that fugitive emissions (B1.2) will decarbonise due to replacement with less damaging refrigerants.

Therefore, to reflect a likely scenario for the decarbonisation of the sector to 2050 and beyond, and to ensure a simplified calculation, when material decarbonisation is assessed, the decarbonisation scenarios shown in Table 15 should be used to adjust the embodied impacts for all products, wherever they are sourced from. Appendix O provides more explanation for the material decarbonisation scenario provided.

Results both with and without material decarbonisation, according to Table 15, must always be reported.

Module	Year of RSP		Decarbonisation scenario
	Buildings	Infrastructure	
A0–A5	Year 0	Year 0	No decarbonisation.
B1.1 (emissions and removals from materials)	0–60	0–120	No decarbonisation.
B1.2 (fugitive refrigerant emissions)	0–60	0–120	50% decarbonisation for all predicted impacts.
B2–B4	0–60	0-120	50% decarbonisation for all predicted impacts.
B5 (excluding biogenic carbon)	0–30	0–30	Decarbonisation % based on 1.66 x year of performance change for all predicted impacts (e.g. 16.6% if planned change occurs in year 10).
B5 (excluding biogenic carbon)	30–60	30–120	50% decarbonisation for all predicted impacts.
B5 (biogenic carbon only)	0–60	0–120	No decarbonisation.
C1–C2	Year 60	Year 120	50% decarbonisation for all predicted impacts.

Module	Year of RSP		Decarbonisation scenario
	Buildings	Infrastructure	
C3–C4	Year 60	Year 120	No decarbonisation.
D1	Year 60	Year 120	50% decarbonisation for all predicted impacts.

Table 15: Decarbonisation scenarios for embodied impacts

For example, if B5 models a change in performance in year 10, the decarbonisation rate for B5 impacts will be 1.66 x 10 = 16.6%. If the change is in y20, the rate will be 1.66 x 20 = 33%.

Decarbonisation is considered after calculated data without decarbonisation has been reported, using the reporting templates.

Further information on the background to decarbonisation of materials is provided in Appendix O.

4.11.6 Carbon offsets, and temporary and permanent carbon storage

Carbon offsets, temporary carbon storage and permanent biogenic carbon storage (for example in landfill or carbon capture and storage) are not to be considered in the calculation of the GWP impact in EPD according to EN 15804+A2.

Therefore, carbon offsets, temporary carbon storage and permanent biogenic carbon storage must not be considered as part of the calculation of WLC at product or asset level.

Permanent carbon storage of fossil carbon through CCUS must not be considered as part of the calculation of WLC at product or asset level unless the following conditions are met.

For carbon capture and storage:

- **Scenarios must not include processes or procedures that are not in current use, or that have not been demonstrated to be practical.**
- **Scenarios must account for:**
  - **any release of CO_2 from leakage, predicted failure, etc. over 100 years, and**
  - **the full impact of operating and maintaining any capture and storage system for 100 years.**
- **Mass balance approaches must not be used to capture and store fossil, rather than biogenic, carbon if a mix of biogenic and fossil carbon is emitted from the process.**
- **If biogenic carbon is captured and stored, it must be modelled as a transfer to nature and treated as an emission.**

For carbon capture and usage:

- **Scenarios must not include processes or procedures that are not in current use, or that have not been demonstrated to be practical.**
- **The full impact of operating and maintaining any capture and usage system must be modelled and, if allocated, the sum of the allocated inputs and outputs shall be equal to the inputs and outputs of the unit process before allocation.** This means no double counting or omission of inputs or outputs through allocation is permitted.
- **If biogenic carbon is captured and used in another product, it must be modelled as a transfer to the next product system, treated as an emission in the system emitting biogenic carbon and treated as a removal in the system using the captured biogenic carbon.**
- If fossil carbon is captured and transferred to another product system:
  - **Any emission of the captured fossil carbon in the next product system must be considered as an emission in that system.**
  - **If the system producing the captured fossil carbon does not report the emission of captured fossil carbon, the system using the captured fossil carbon must not claim or report any benefit from the use of the same captured fossil carbon, as this would involve double-counting the benefit.**
  - **If the system using the captured fossil carbon claims or reports a benefit from the use of captured fossil carbon (e.g. reports a removal of fossil carbon when the fossil carbon is used), the system producing the captured fossil carbon must report a corresponding emission, as otherwise this would involve double-counting the benefit.**
- **Mass balance approaches must not be used to model the capture and use or storage of fossil, rather than biogenic, carbon if a mix of biogenic and fossil carbon is emitted from the process.**

Appendix N provides information on the benefits of long-term biogenic carbon storage and how it can be illustrated as additional information.

5 Assessing life cycle stages within the modular structure

This section provides details and practical guidance on each life cycle stage and information module, in order to enable consistency of interpretation when conducting a WLCA. It refers to EN 15643:2021, which provides the framework of life cycle stages and information modules used in EN 15978, EN 17472 and EN 15804. It references the requirements and guidance provided in these standards, and covers all stages of the life cycle of a project.

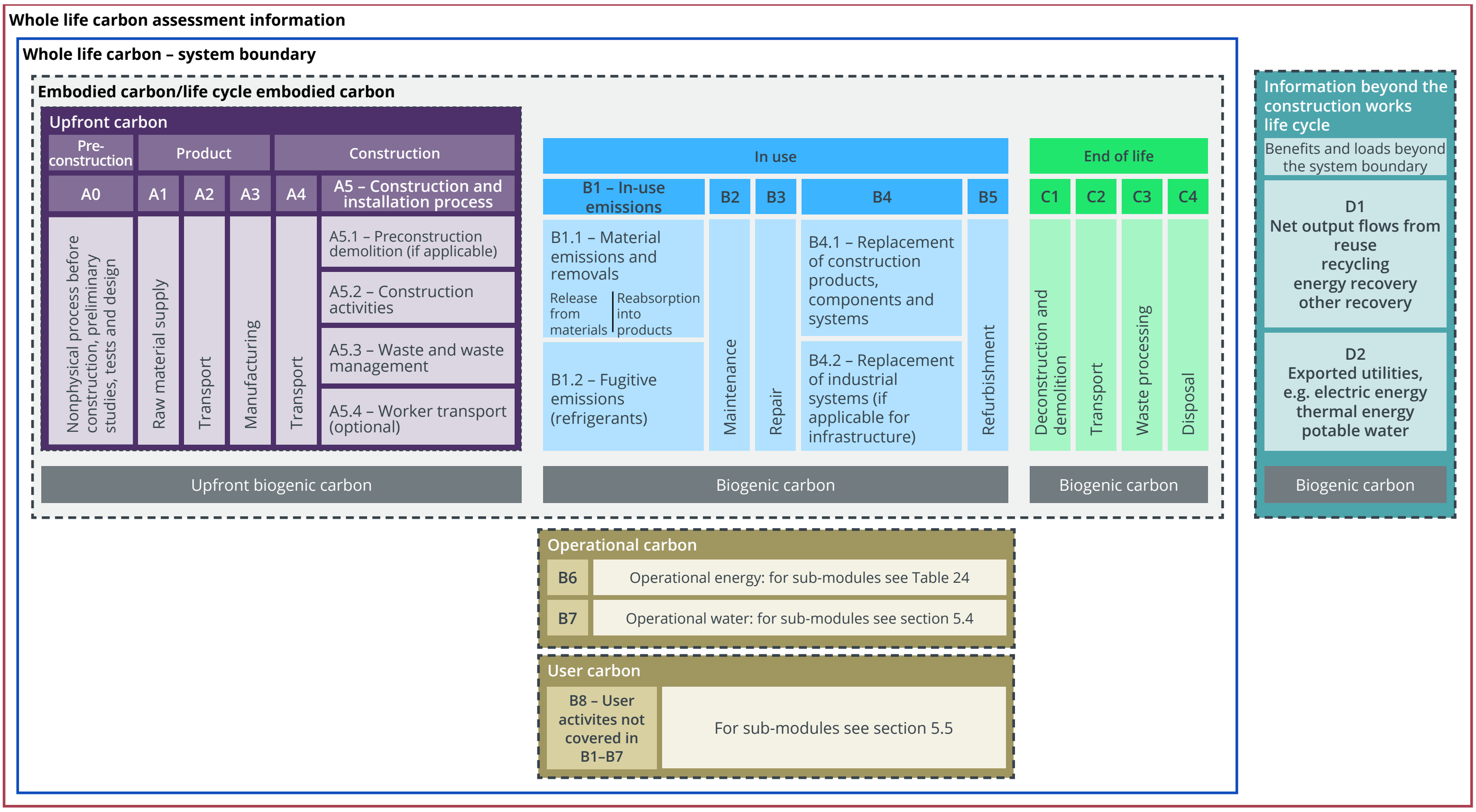


Figure 11: Modular diagram expanded from the standards referenced above, including sub-modules described in this section and optional modules A0 and B8, adapted to include the system boundary

The WLCA reporting templates include all modules and sub-modules.

5.1 Pre-construction, product and construction stages (A0–A5)

5.1.1 Pre-construction stage (A0)

Activities in A0 include, but are not limited to, non-physical processes before construction such as preliminary studies, impact assessments, risk assessments, stakeholder engagement, design and technical studies, product/material tests, site surveys and acquisition of land and design.

Such activities typically have much lower direct environmental impacts compared to the rest of the life stages of built assets. However, they can be included in the WLCA scope, depending on the purpose of the assessment, particularly for large infrastructure projects, masterplans and mixed-use schemes, structures in especially challenging conditions, etc., where non-physical processes like ground investigation may be significant, or where design offices are established and/or air travel is required for site visits by the design team. A0 for such non-physical processes should include any impacts arising from the transport and operation of any equipment required, as well as any materials used on- or offsite for associated activities (excluding embodied carbon of testing equipment and vehicles used). The carbon impacts of associated business activities should be assessed based on the Greenhouse Gas Protocol with an operational boundary of scope 1, scope 2 and scope 3 business travel (see GHG Protocol Technical Guidance for Calculating Scope 3 Emissions, chapter 6). See section 4.8 for the emissions factors to be used.

5.1.2 Product stage (A1–A3)

The product stage deals with the carbon impacts attributable to cradle-to-gate processes: raw material extraction and supply, transport and manufacturing. This subsection provides additional details to assist in calculating the carbon impacts 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 steps need to be taken into account.

The carbon impacts attributable to the product stage of the items included in the WLCA must be calculated by assigning suitable embodied carbon factors to the elemental material quantities.

For example:

A1–A3 = material quantity × material embodied carbon factor

Guidance on evaluating material quantities is provided in section 4.5. Acceptable carbon data sources and guidance are included in section 4.7 and Appendix B.

The assessor needs to ensure that the material quantity and the appropriate material embodied carbon factor are measured against the same metric, such as per kg, per m^3 or per m^2, or are adjusted to do so using appropriate modification factors, such as densities where necessary to convert from mass to volume and vice versa.

Density data should be sourced from the relevant EPD 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 the source clearly stated in the WLCA report. Project team members such as the structural engineer and cost consultant should be consulted for clarification on material assumptions if necessary.

During the early design phase, the technical specification is likely to be indicative, without detailed information on building components and product types. Subjective material selections made early in the design process due to a lack of detailed information on technical specification can heavily influence the product stage carbon impacts (A1–A3). This can lead to significant discrepancies between results for similar projects at the early design phase, and influence the improvements claimed in subsequent WLCAs. A 'worst-case scenario' as a starting point will show higher reductions through applying standard practice improvements.

Therefore, during the very early design phase of a project, when initial WLCAs are being conducted to act as a baseline for progressive assessment, the processes set out in sections 4.5 (material quantities) and 4.5.2 (assumptions) should be followed. This data should be refined during later project phases and replaced by more comprehensive and product-specific information as it becomes available.

To ensure baseline consistency, for UK assets the following assumptions must be used in early design phase WLCAs that are to act as baselines for progressive reporting. These assumptions should also be retained during later project phases, until such time as it can be demonstrated that more detailed, project-specific information is available, and there is confidence of the procurement and adoption of these materials in the project (see Table 16).

The values in Table 16 are based on UK average industry standard practice. Assessments in other countries may use these default figures but should use their national equivalents. The WLC assessor should clearly indicate for which items the generic assumptions of Table 16 have been used. These assumptions should be updated according to project-specific information as it becomes available, and the assessment should make clear what source has been used.

Material	Details	Baseline specification representative of standard practice (UK)
Concrete, cast in situ (ready-mix concrete) Assumptions for reinforcement provided separately)[2]	Piling and foundations	Reinforced concrete, C32/40, 25% cement replacement[2]
	Vertical structural elements, e.g. columns, walls	Reinforced concrete, up to 20 storeys (in situ, C32/40, 25% cement replacement, excluding reinforcement)[2] Structure, concrete, over 20 storeys (in situ, C40/50, 25% cement replacement[2]
	Horizontal structural elements, e.g. beams, slabs	Reinforced concrete (C32/40, 25% cement replacement)[2]
	Facilitating/auxiliary works	Reinforced concrete (C16/20, 25% cement replacement)[2]
	Backfill	Reinforced concrete (C8/10, 25% cement replacement)[2]
Concrete, precast	Structural elements: beams, segments, slabs, etc. pours of <25m^3	Reinforced concrete (C40/50, 0% cement replacement)[2]
	Structural elements: beams, segments, slabs, etc. pours of >25m^3	Reinforced concrete (C40/50, 25% cement replacement, excluding reinforcement)[2][17]
	Cladding panels	C16/20, 0% cement replacement[3]
Concrete, sprayed	Tunnel/shaft linings Curved surfaces: roof shells, domes, etc.	Fibre reinforced concrete, C32/40, 0% cement replacement)[2]
Concrete reinforcement	Reinforcement bars	UK CARES sector average[4] (EAF production, typically 96% recycled content in UK)

Material	Details	Baseline specification representative of standard practice (UK)
Steel	Sheet piling	Blended EAF/BOF[5]
	Structural steel sections – rolled sections	Blended market rate[5] of 60% BOF/40% EAF production[7]
	Structural steel sections – plate and closed sections	100% BOF production
	Studwork/support frames	Galvanised steel, 15% recycled content[8]
	Galvanised profiled sheet	UK TATA ComFlor®[6]
Masonry	Precast concrete blocks	Lightweight aerated autoclaved concrete (AAC, such as Aircrete) blocks for non-structural uses (600kg/m^3)[9]
		Medium-density blocks for structural uses (1425kg/m^3)[10]
	Brickwork	Generic UK clay brick, dry brick weight 2.13kg[11]
Timber	Manufactured structural timber: cross-laminated timber (CLT), Glulam, laminated veneered lumber (LVL), etc.	Engineered wood, sustainably sourced[12]
	Studwork (e.g. secondary members such as internal partitions)	Softwood, C16, sustainably sourced[12]
	Framing (e.g. primary members such as joists)	Softwood, C24, sustainably sourced[12]
	Formwork	Plywood, sustainably sourced[12]
Aluminium	Sheet	Aluminium sheet, 31% recycled content[13]
	Extruded profiles	Aluminium extrusions, 31% recycled content[13]

Material	Details	Baseline specification representative of standard practice (UK)
Plasterboard	Partitioning/ceilings	FGD gypsum plasterboard (approximately 10% recycled content)[14]
Insulation	For floors and external walls	Mineral wool[13]
	For roof – polyisocyanurate (PIR)/ rigid polyurethane (PU)	Polyurethane (PU) rigid foam[13]
Aggregates/ granular material	Fill material	Aggregates and sand, general UK fill material, mixture of land won, marine, secondary and recycled, bulk, loose[13]
Glass	Glass: general, glazing, toughened, multi-layer safety, skylight, fibreglass, expanded glass	Relevant generic datasets[13]
Plastics	Plastics (various)	Relevant generic datasets[13]
Coatings	Paints: general, waterborne, solvent-borne	Relevant generic datasets[13]
	Intumescent coating for steel	Amotherm steel WB[6]
	Cementitious spray	Isolatek international product average[6]
Asphalt	For highway and pavement construction	Asphalt, 5% binder content[13]
Bitumen	For road construction, roofing, waterproofing and other applications	Straight run bitumen[13]

Material	Details	Baseline specification representative of standard practice (UK)
MEP products	All	CIBSE TM65 (specification of MEP constituent materials rather than composite assemblies in Table 2.1 from TM65: 2021)
Facade build up	All types[15]	Centre for Window and Cladding Technology (CWCT) How to calculate the embodied carbon of facades: a methodology (refer to Appendix B and Appendix C)[16]

Table 16: Default specifications for main building materials

Notes on Table 16

[1] Use the project-specific concrete strength design properties if available, and combine with the recommended cement replacement rates for baseline purposes. Refer to the structural engineering specification.

[2] Supplementary cementitious materials (SCMs) such as ground granulated blast furnace slag (GGBS) are often used to replace Portland cement. 25% GGBS is the default assumption for UK in situ concrete prior to confirmation of subcontractor sequencing. MPA The Concrete Centre. Concrete Industry Sustainability Performance Report (13th report: 2019 performance data), 2021.

[3] MPA The Concrete Centre. British Precast Architectural & Structural EPD (precast brick-faced concrete cladding), 2019.

[4] UK CARES. Environmental Product Declaration: Carbon Steel Reinforcing Bar (secondary production route scrap), sector average, 2023.

[5] The carbon factor of steel for modules A1–A3 varies depending on its recycled content and production method: basic oxygen furnace (BOF) or electric arc furnace (EAF). BOF is a fossil fuel-fired (mostly coal) production process that produces steel from high proportions of virgin iron ore compared to scrap metal (maximum 30% scrap, and typically 13% in the UK). EAF is a process powered by the electricity grid and can produce steel made with a very high recycled content (up to 100%, and typically 97% in the UK). Steel produced by EAF with a high recycled content generally has a much lower A1–A3 carbon factor than BOF-produced steel, and this may reduce further in the future as electricity grids decarbonise.[6]

[6] The Institute of Structural Engineers, How to calculate embodied carbon, second edition, March 2022.

[7] BSCA/Steel for Life/SCI. UK average embodied carbon of structural steel. Due to the significance of global supply chain and manufacturing processes, refer to [6] for carbon

factors and updated market consumption average data where its publication date is more current than this standard.

[8] Waste Resources Action Programme (WRAP), *Choosing construction products – Guide to the recycled content of mainstream construction products*, 2008.

[9] The type of aggregate used to differentiate the lightweight block constitutes the difference in resulting embodied carbon factors. Special care should be taken when specifying blocks used in Europe, as aggregate (expanded clay, pumice, perlite) may vary from what is used in the UK.

[10] MPA, UK Concrete Block Association (CBA) EPD, generic concrete block.

[11] Brick Development Association (BDA), generic UK clay brick EPD.

[12] The following scenarios are allowable under EN15804+A2:

- sustainably managed and certified forest: any forests that are operating under established, independent third-party certification schemes for sustainable forest management (e.g. FSC, PEFC, UKWAS, GiB)
- non-native forest, short-term forests, degraded forests, managed forests or forests with short-term or long-term rotations (e.g. UK Forestry Standard), and
- reused or recycled timber (irrespective of original source).

The UK government's Timber Procurement Policy (TPP 2013) and the GLA Group Responsible Procurement Policy (2021) further underpin sustainable timber sourcing as a requirement. Sustainable timber sourcing (legally harvested and traded timber) is also mandatory for obtaining BREEAM certification. **Where full FSC, PEFC or Grown in Britain certification is required, the claim must be noted as FSC 100%, FSC Mix xx%*, FSC Recycled xx%, 100% PEFC Origin, xx%* PEFC Certified, GiB-FP or GiB-S.**

*Minimum 70%. BRE requirement for 100% of timber to be compliant.

[13] Embodied Carbon – The ICE Database.

[14] 10% of gypsum as a component of the total system is recycled. Improving and using recycled gypsum (Knauf statement), 2020.

[15] For components and systems that are prefabricated offsite, it is important to account for the transport of materials to the factory (A2), and the manufacturing and wastage that occur in the factory (A3) where practicable, rather than just adding up the product impacts (A1–A3) of the individual constituents. See the guidance from the Centre for Window or Cladding Technology [16] for information on how to account for this, and for some default values if an EPD is not available for the component or system.

[16] Centre for Window and Cladding Technology Embodied Carbon Committee, 2022. How to calculate the embodied carbon of facades: a methodology. Bath, CWCT.

[17] Assumed allowance for cement replacement in larger pour precast concrete element to control concrete temperatures.

5.1.3 Transport impacts (A4)

Module A4 captures the impacts associated with the transportation of the materials and components from the factory gate to and from the project site.

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

The scope of A4 does not include transport impacts from construction workers, which are covered under A5.

Transport impacts should be calculated as follows:

> A4 = material or product mass (a) x transport distance (b) x [carbon conversion factor outward (c1) + (empty running factor x carbon conversion factor return (c2))]

Material or product mass (a): should be obtained from acceptable sources, as specified in section 4.7, 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. During the early design phase prior to onboarding the delivery programme, or when specific sourcing information is unavailable, the transport scenarios in Table 17 should be used in WLCAs for UK-based projects. The assessor, in consultation with the design team, should reasonably allocate the anticipated products and components into each of the categories: locally, regionally, nationally, European and globally manufactured, to inform the transport scenario.

Transport scenario (both road and sea to be used)	km by road*	km by sea**
Locally manufactured (ready-mixed concrete)	20[1]	-
Locally manufactured (general), e.g. aggregate, earth, asphalt	50[2]	-
Regionally manufactured, e.g. plasterboard, blockwork, insulation, carpet, glass	80[2]	-
Nationally manufactured, e.g. structural timber, structural steelwork, reinforcement, precast concrete	120[2]	-
European manufactured, e.g. cross-laminated timber (CLT), facade modules	1,500[4]	100[4]
Globally manufactured, e.g. specialist stone cladding	500[5]	10,000[5]

Table 17: Default transport scenarios for UK projects

* Means of transport assumed as average of all average rigid HGVs or other road vehicles where details available (average laden). See definition for carbon conversion factors (c1 and c2) below.

** Means of transport assumed as average container ship.

Notes on Table 17

[1] Mineral Products Association (MPA).

[2] BRE Global Product Category Rules (PCR) for Type III EPD of Construction Products to EN 15804+A2 (2023).

[3] EeB Guidance Document, Part B: Buildings – Operational guidance for life cycle assessment studies of the Energy-Efficient Buildings Initiative, p.199.

[4] Generic distance for items assumed to be sourced from Central and Eastern Europe, e.g. Austria.

[5] Generic distance for items assumed to be sourced from Eastern Asia.

The distances in Table 17 are applicable to projects located in the UK and include a generic allowance for interim storage depots before reaching the construction site. Similar default scenarios should be developed for different countries outside the UK.

Carbon conversion factor outward (c1): based on the selected mode of transport, suitable carbon conversion factors such as tonnes per km should be used. The conversion factor should be attributed to the outward journey. Carbon conversion factor outward should be based on an average-laden delivery vehicle. An average rigid truck should be assumed if no other data is known.

Empty running factor: to account for the empty return journey. Empty running for UK road freight is typically 43% of the loaded journey, so 43% should be used in the UK, unless a return load is not possible (e.g. for concrete mixers), where 100% should be used. For transportation routes by sea or rail, the empty running factor is normally 0%, as it is assumed that vehicles are typically always laden.

Carbon conversion factor return (c2): based on a 0% laden delivery vehicle, accounting for the empty return to the delivery site. For transportation routes by sea or rail, carbon conversion factors for the return journey are not applicable, as it is assumed that vehicles are laden on their return and applicable to a new project.

These assumptions should be updated as project-specific evidence from the main contractor and subcontractors becomes available, including alternate lower-emission fuels where it can be demonstrated that these have been adopted.

5.1.4 Construction: installation process (A5)

The carbon impacts arising from any on-site construction-related activities must be considered in module A5.

This includes any demolition works associated with refurbishment or redevelopment of existing built assets or sites; temporary works associated with installation processes; any construction activities and installation processes on-site, including energy consumption for site accommodation and use of plant, machinery and equipment; and the impacts associated with any waste generated through the construction process, its treatment and disposal, including the disposal of packaging waste.

Module A5 should be split and reported as four separate sub-modules:

A5.1 Pre-construction demolition (if applicable)	+	**A5.2 Construction activities**	+	**A5.3 Waste and waste management**	(+)	**A5.4 Worker transport (optional)**
Demolition/ deconstruction of existing buildings and structures, and/ or parts thereof, including transport from site and waste processing of removed materials.		Site preparation; temporary works; ground works; connection to utilities; transport and onsite storage of construction products, materials and equipment; onsite production/assembly of products; works for the installation and ancillary materials (e.g. formworks and their disposal); heating/ cooling/ventilation of site facilities; energy and water use for construction processes and landscaping.		Production, transportation, storage and end-of-life treatment and disposal of any material/waste on-site; transport, waste management and disposal of packing materials.		Emissions of site workers travelling to and from site.

Figure 12: Sub-modules of module A5

Any emission rates used for specific processes such as concrete pouring, excavations and earthworks, craneage and lifting should be documented as much as practicable.

Where construction impacts (A5) data is available from the component/product EPDs or equivalent allowable sources, these figures should be handled with care, as they need to be cross-referenced against project-specific building construction practices. If the assembly and construction methods anticipated coincide with those specified in the respective EPDs, the data from them can be used in the assessment until project-specific relevant information becomes available.

Any $kgCO_2e/m^2$ values suggested in the guidance should be refined by substitution with site monitoring data provided by the project contractor, as this becomes available. At project completion, actual waste data should be documented and its impacts reported in A5.3.

Pre-construction demolition (A5.1)

Deconstruction/demolition of the existing built asset is essentially the same as the C1–C4 end-of-life impact of the existing built asset. However, to inform decision-making when comparing designs for retrofit/refurbishment or new-build options during the concept design phase, the deconstruction/demolition impact of fully demolished buildings, as well as retrofit/refurbishment schemes, are to be reported under A5.1 as part of the upfront carbon impact.

For all schemes, any carbon impacts resulting from the deconstruction/demolition, transporting and disposal of waste as part of the main works must be accounted for in A5.1, which should be reported separately.

To calculate the carbon impacts associated with pre-construction demolition, actual figures should be used where possible, including transport to waste processing, and waste processing and disposal impacts themselves. If actual figures are not available, a standard assumption for the UK of 35 $kgCO_2e/m^2$ should be adopted (rate from monitored demolition case studies in central London), applied to the GIA of the existing areas being demolished that fall within the boundary line. Assessments in other countries may use these default figures, but should use a national equivalent if available; the assessment should then make clear what source has been used. The $kgCO_2e/m^2$ value suggested should be superseded with site-specific data when available. The loads and benefits of recovery of any pre-demolition waste should be considered in module D1.

Construction activities (A5.2)

Construction activity impacts include impacts from any construction activities and installation processes on-site, including temporary works, energy consumption for site accommodation and use of plant, machinery and equipment. These should be monitored during construction to contribute to an accurate as-built embodied carbon calculation at project completion.

In order to ensure consistency across projects, contractors should scope out what accounts for 80% of their anticipated impacts on site and identify a methodology for how it can be reduced prior to works commencing on site. Example actions may include removing diesel or using hydrogen for tower cranes.

Key temporary works required to enable construction should be captured in the WLCA, as they form part of the works related to the built asset. Such works are captured under the relevant element categories: facilitating works, preliminaries, etc. Particularly for large projects, temporary works may be significant. Examples may include formwork, hoarding posts, tower crane grillage, scaffolding, piling mats, temporary sheet piling, temporary cofferdams, temporary props and retaining structures such as struts and walers. Impacts should cover the material impact, the transportation of items between temporary storage facilities and the site, and their disposal.

Where temporary works are reusable, an estimate of their reuse should be made so that the project accounts for the appropriate proportion of the impacts, in line with its use. Use of timber in temporary works should be assessed as described in section 4.11.1, and reusable steelwork formwork may be assumed to be used 20 times in the absence of more accurate information.

It is recommended that the embodied carbon of key temporary hired equipment, such as lifting platforms, scaffolding, struts and support steel frames, are estimated and captured accordingly, so that the project accounts for the appropriate proportion of the impacts in line with its use of the temporary equipment. For example, if the average lifespan of scaffolding components is 20 years and it is being used on a project's construction site for 2 years, then the fraction of embodied impacts that can be attributed to the project is 2/20, so 10% of the total embodied carbon (A1–A5, plus C1–C4) of the scaffolding used.

Baseline building-specific impacts related to construction activities in the UK are anticipated to be 40 $kgCO_2e/m^2$ GIA. Assessments in other countries may use this default figure but should use a national equivalent if available; the assessment should then make clear what source has been used.

The $kgCO_2e/m^2$ value suggested should be superseded with site-specific data when available.

In the case of modern methods of construction (MMC) or any other prefabricated elements, any offsite-related activities are considered part of the fabrication process to be reported under A1–A3 (see section 5.1.2). The Centre for Window and Cladding Technology also provides some guidance on this.

Waste and waste management (A5.3)

The embodied carbon from the production and transport of products that will be wasted, and any impacts associated with waste treatment, should be included in the calculations in this sub-module. Installation and deconstruction impacts can be assumed to be zero, as the wasted material is not being installed. The waste treatment of packaging waste is also included in A5.3. Packaging waste in the UK can be assumed to be 32% of the total mass of construction waste if no other data is available. Assessments in other countries may use this default figure but should use a national equivalent if available; the assessment should then make clear what source has been used.

Waste and waste management impacts should be calculated as follows:

A5.3 = waste rate (a) x site waste treatment embodied carbon factor (b)

Waste rate (a): the waste rate (WR) is a percentage of the quantity of materials brought to the site that are wasted.

The WRs outlined in Table 18 are based on traditional forms of construction in the UK; therefore, WRs associated with offsite manufacture would be expected to be lower. For MMC that involve prefabrication, any manufacturing waste at offsite facilities should be captured in the A1–A3 carbon of the respective products; see the guidance from the Centre for Window and Cladding Technology.

Material/product	WR (waste rate)
Concrete in situ	5%
Concrete precast (floor, beams and frames)	1%
Concrete (sprayed)	10%
Steel reinforcement	5%
Steel frame (beams, columns, braces)	1%
Concrete blocks (lightweight AAC)	10%
Concrete blocks (dense/medium density)	5%
Brickwork (clay)	6%
Stone (cladding)	5%
Stone (landscaping)	10%
Mortar and render (internal and external)	4%
Screed	8%
Floor finish (tile)	6%
Floor finish (carpet)	6%
Timber frames (beams, columns, joists, braces)	2%
Timber floors (boards)	10%
Timber formwork	10% (in addition to end-of-life usage rates, see section 4.11.1)
Aluminium sheet	1%
Aluminium extruded profiles/frames	1%
Plasterboard	4%
Insulation	7%
Aggregate	10%
Glass	1%
Coatings (paint, intumescent coatings)	6%

Material/product	WR (waste rate)
Sprayed cementitious fire protection to steel	10%
Asphalt	6%
Bitumen	6%
Roof cladding	5%

Table 18: Recommended waste rate data, primarily from BRE Global Product Category Rules (PCR) for Type III EPD of Construction Products to EN 15804+A2 (2023) or SmartWaste

Any site waste data from EPDs should be superseded by the rates from Table 18 for consistency purposes in the UK. This is due to the generalisation in EPD site waste rates. Assessments in other countries may use these default figure but should use national equivalents if available; the assessment should then make clear what source has been used. These rates should subsequently be refined by substitution with project-specific information and/or site monitoring data provided by the contractor and subcontractors as these become available. At project completion, actual wastage rates should be documented.

Site waste disposal embodied carbon factor (b): The site waste disposal embodied carbon factor is informed by the principles outlined for the product and transport stages (A1–A3 and A4), and the end-of-life stages (C2–C4). The factor varies based on the disposal scenario, as shown in Table 19.

Disposal to landfill/incineration	Reuse or recycling on-site	Reuse or recycling offsite
[A1–A3] + [A4] + [C2] + [C4]	[A1–A3] + [A4] + [C3]	[A1–A3] + [A4] + [C2] + [C3]

Table 19: Calculating the construction waste embodied carbon factor for different site waste disposal scenarios

End-of-life scenarios should be established (and aligned with the recommendations of section 5.6.1) in accordance with the impacts calculated using the formulas in Table 19. The selection of on-site or offsite reuse/recycling scenarios for the different items should be based on project-specific information.

Worker transport (A5.4)

The transport of people and commute of employees is excluded from the calculations in section A4, unless they are bringing materials with them, as the impacts associated with these activities are not attributable to the project but to the individual employees.

Documentation of this element is optional; however, if it has been quantified, it can be reported separately in A5.4.

Any calculation of impacts should be based on the allowable carbon data sources in section 4.8 and should account for return journeys.

5.2 In-use stage (B1–B5)

The in-use stage must capture the carbon impacts associated with the operation of the built asset over its entire life cycle, from project completion to the end of the RSP. See section 4.2 for RSPs required for compliance with this standard.

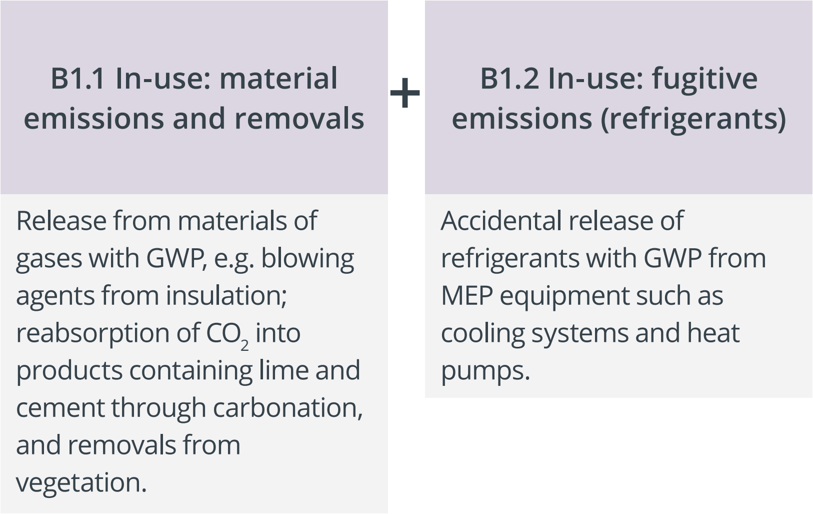
This includes any carbon impacts relating to operational energy and water use; user activities; and any embodied carbon impacts associated with in-use impacts, maintenance, repair, replacement and planned refurbishment of built asset components and systems.

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

5.2.1 In-use impacts (B1)

The in-use module (B1) captures the non-energy-related impacts during the life of a built asset arising from its components.

It is considered using two sub-modules to account for emissions and removals from materials (B1.1) and fugitive emissions of refrigerants (B1.2):



B1.1 In-use: material emissions and removals

Release from materials of gases with GWP, e.g. blowing agents from insulation; reabsorption of CO_2 into products containing lime and cement through carbonation, and removals from vegetation.

+

B1.2 In-use: fugitive emissions (refrigerants)

Accidental release of refrigerants with GWP from MEP equipment such as cooling systems and heat pumps.

Figure 13: Sub-modules of module B1

Any non-energy-related carbon removals or emissions arising from components during the life of the built asset must be reported in B1.

Carbon emissions released from building elements and the impact of potential carbon absorption should be accounted for.

Details on how to account for the impacts of the carbonation process in items containing exposed concrete and/or lime are provided in section 4.11.2. Carbon absorption by green roofs and facades is considered negligible for green areas of less than 1,000m^2 unless otherwise stated. Carbon absorption potential for green roofs and facades should be supported by relevant evidence, such as a landscape consultant/ecology report, to be included in the WLCA. Care should be taken that the disposal of any waste biomass from the maintenance of green roofs and facades during operation is considered in B2, and at the end of life in C3 or C4.

Particular attention should be paid to any emissions arising from refrigerants and insulation blowing agents with GWP over the life cycle of the project.

Annual refrigerant leakage from MEP equipment must be accounted for, as detailed in CIBSE TM65.

The equation for calculating the accidental release of refrigerants with GWP from mechanical equipment (B1.2) is:

B1.2 = refrigerant charge x refrigerant GWP x annual leakage rate x RSP

5.2.2 Maintenance impacts (B2)

For all built assets, regular maintenance, including cleaning, helps extend their life and is important to avoid deterioration of key building elements such as facades, MEP systems and internal spaces, as well as ensuring continued efficiency, good appearance and the validity of warranties. Deterioration leads to unnecessary waste, repair and replacement, which then results in increased carbon impacts over the life cycle of the asset. Repetitive maintenance activities involve the use of energy and/or products, and should be accounted for in B2.

Module B2 must account for the carbon impacts from any activities relating to maintenance processes, including cleaning, as well as any relevant products used and waste produced over the RSP.

It should include any impacts from the energy and water use associated with these activities.

The impacts of the energy and water used in situ for maintenance (B2) or repair (B3) of the asset and its components will most likely not be distinguishable in the metered energy consumption (B6) or operational water use (B7). This should be taken into account when comparing the results of pre- and post-construction assessments.

Maintenance-related carbon impacts (B2) should be reported for all relevant building element categories. 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, facade access and maintenance strategies, life cycle cost reports, operations and maintenance manuals, and professional guidance such as CIBSE Guide M and RICS NRM 3.

Relevant carbon data from EPDs should be adjusted according to the project-specific maintenance scenario. For building services, the CIBSE TM65 method should be followed to estimate B2 impacts.

Alternatively, for module B2 impacts in the UK, a total figure of 10 $kgCO_2e/m^2$ gross internal area (GIA) may be used to cover all building element categories, or 1% of modules A1–A5, whichever is greater – as per the London Plan Guidance for Whole Life-Cycle Carbon Assessments (March 2022). Assessments in other countries may use this default figure but should use a national equivalent if available; the assessment should then make clear what source has been used.

5.2.3 Repair impacts (B3)

Module B3 is intended to provide a reasonable allowance for repairing unpredictable damage over and above the maintenance regime, where repairing a product or system involves returning it to an acceptable condition through the renewal, replacement or mending of individual worn, damaged or degraded parts. It is therefore applicable to the same element and infrastructure categories as maintenance impacts.

Module B3 must take into account carbon impacts from all activities that relate to repair processes, and any products used and waste produced over the RSP. All impacts from the production, transportation to and from site, and installation of the repaired items must be included.

This extends to cover any losses during these processes, including the disposal of failed parts.

Data from facilities management/maintenance strategy reports, facade access and maintenance strategy, life cycle cost reports, operations and maintenance manuals, and other professional guidance should be used to develop scenarios for repair.

If none of these sources are available, in the UK repair impacts should be assumed as equivalent to 25% of B2 maintenance impacts for the relevant items and 10% of A1–A3 impacts for MEP – in accordance with the CIBSE TM65 methodology. Assessments in other countries may use these default figures but should use national equivalents if available; the assessment should then make clear what source has been used.

5.2.4 Replacement impacts (B4)

For the purposes of consistency, a WLCA must assume the like-for-like replacement of products, components and systems as required over the RSP. These replacements must be reported in B4.

Over the RSP of an asset, replacement will occur at different cycles depending on the original specification and detailing, the maintenance regime and the consequent life expectancy of the different elements.

Module B4 must take into account any carbon impacts associated with the anticipated replacement of built asset components, including any impacts from the replacement process, over the RSP. All impacts from the production, transportation to site and installation of the replacement items must be included, as well as any losses during these processes, as well as any impacts associated with the removal and end-of-life treatment of replaced items.

For both buildings and infrastructure, the repair and replacement impacts must be considered using the same data for materials and products as was used in modules A1–A5 for installation and modules C and D for their end of life.

Any loads and benefits beyond the system boundary from the recovery of materials from A5 or C1–C4 will also be used for the recovery of any materials in B4, reported in D1.

Module B4 should be split and reported as two separate sub-modules:

B4.1 Replacement of construction products, components and systems	(+)	B4.2 Replacement of industrial systems (if applicable for infrastructure)
Replacement, including manufacture, transport and installation of new, like-for-like products, components or systems, as well as the deconstruction and waste treatment of removed products, components and systems.		Accidental release of refrigerants with GWP from MEP equipment such as cooling systems and heat pumps.

Figure 14: Sub-modules of B4

For infrastructure projects, it may be helpful to separate the replacement of a) products and components most closely associated with the constructed asset (the shell) from b) those that are purely used to provide the output of the asset (the service). For example, replacing the roof covering of a water treatment works would be in the first category (B4.1), whereas replacing its pumps would be in the second (B4.2). For buildings, this separation is not considered necessary.

Replacement (B4.1)

The carbon impacts for the replacement of items from all relevant building element categories should be reported; see sections 4.4.1 for buildings and 4.4.2 for infrastructure (see also the Building element categories supporting document or Appendix C for infrastructure). Additional items should be included if specific information on their replacement is provided.

Appropriate life cycle scenarios that will set out the expected replacement cycles for the different components should be developed and clearly explained in the WLCA report. In the UK, the lifespans provided in Table 20 should be used for the components listed, in the absence of more specific data. Assessments in other countries may use these default figures but should use national equivalents if available; the assessment should then make clear what source has been used.

Building part	Building elements/components	Expected lifespan
Substructure	Piling and foundations Lowest ground floor	60 years (or building lifespan)
Superstructure: frame, upper floor and roof structure	Structural elements, e.g. columns, walls, beams, upper floor and roof structure	60 years (or building lifespan)
Facade	Opaque modular cladding:	
	Rain screens, timber panels	30 years
	Brick, stone, block and precast concrete panels	60 years
	Glazed cladded/curtain walling	35 years
	Windows and external doors:	
	Hardwood/steel/aluminium windows	30 years
	Doors	20 years
Roof	Roof covering:	
	Single-ply membrane	30 years
	Standing seam metal	30 years
	Tiles, clay and concrete	60 years

Building part	Building elements/components	Expected lifespan
Superstructure	Internal partitioning and dry lining:	
	Studwork	30 years
	Blockwork	60 years
Finishes	Wall finishes:	
	Render/paint	30/5 years respectively
	Floor finishes:	
	Carpet/vinyl	7 years
	Stone tiles	25 years
	Raised access floor (RAF) pedestal/tile	50/30 years respectively
	Ceiling finishes:	
	Substrate/paint	10 years
	Suspended grid (ceiling system)	25 years
FF&E	Loose furniture and fittings	10 years

Building part	Building elements/components	Expected lifespan
Services/MEP	Heat source, e.g. boilers, calorifiers	20 years
	Heat source, e.g. heat pumps (except ground source)	15 years (20 years)
	Space heating and air treatment	20 years
	Central cooling systems (cooling only), e.g. fan coil systems, variable air volume, variable refrigerant volume	15 years
	Ductwork: Galvanised Plastic or flexible	 40 years 15 years
	Electrical installations	30 years
	Lighting fittings	15 years
	Communications installations and controls	15 years
	Water and disposal installations	25 years
	Rainwater harvesting and grey water collection	30 years
	Sanitaryware	20 years
	Lift and conveyor installations	20 years
Hard landscaping	Asphalt Concrete and stone paving Timber decking	35 years 60 years 15 years

Table 20: Indicative component lifespans

These figures should be replaced with scenarios based on the actual life expectancies of the specific items to be used in the project as information becomes available. Such scenarios should be specific to the building or infrastructure asset type, and could be based on data from facilities management and maintenance strategy reports, facade access and maintenance strategies, life cycle cost reports, operations and maintenance manuals, guidance (e.g. CIBSE Guide M and BCIS Life Cycle Evaluator), international standards (e.g. ISO 15686-1:2011, ISO 15686-2:2012, ISO 15686-7:2017, ISO 15686-8: 2008 Buildings and constructed assets – service life planning and BRE Global Product Category Rules (PCR) for Type III EPD of Construction Products to EN 15804+A2 (2023) Appendix D for scenario default values) and manufacturers' documentation.

The number of replacements for a product, component or element used in the asset is directly linked to its expected lifespan and the RSP. Only a whole number of replacements (no partial replacements) is allowed; in the case of a partial number of replacements resulting from the estimated service life of the component and the RSP of the building, the number is rounded up.

If, after the last scheduled replacement of a product, the remaining RSP for the built asset is significantly less than the expected lifespan of the installed product, the actual likelihood of this scheduled replacement should be taken into account.

The treatment of biogenic carbon for the replacement of biobased materials during the RSP should be in accordance with section 4.11.6.

For building services equipment, follow the CIBSE TM65 method (and local TM65 addendum assumptions if the product is installed outside the UK) to calculate the carbon impacts in modules A1–A3. For impacts in other life cycle modules, follow the relevant parts of this methodology.

Replacement of industrial systems (B4.2, optional)

Sub-module B4.2 can be used to capture the replacement of industrial machinery/technical systems housed by infrastructure assets that are essential to enable the infrastructure's function and deliver the intended outputs, but are not strictly related to the built asset/civil engineering works or normally considered as construction products. This might include, for instance, water treatment equipment in a water treatment works, or electricity generation turbines in a power station.

Impacts for the replacement of these systems or components should be assessed based on the same principles as for constructed components in B4.1 but can be reported in B4.2.

5.2.5 Impacts from retrofit/refurbishment/planned changes (B5)

Retrofit and refurbishment, as distinct from replacement (B4), are defined here as a planned alteration or improvement to the physical characteristics and/or performance of the built asset, for it to perform a future function that was identified as likely at the time of the assessment. This would typically involve a predetermined change that will occur during the service life of the project. It is likely to be a sizeable amount of works to the asset, for example an extension, alteration or internal change planned to occur in the future.

Determining whether the replacement of material is to be included under B4 or B5 will depend on whether there is no change or improvement to the function or performance of the asset over the reference study period (B4), or it is part of a planned improvement of the asset required by the owner at the outset (B5). For example, a major change to the internal layout and/or building envelope; a change of the technical systems relating to heating, cooling or air conditioning; modifications for the purposes of a planned or expected change of use; a planned retrofit/refurbishment; or a change to the number of storeys would all be considered under B5.

A module B5 assessment should include the same scope as module A, as illustrated in Figure 15, with adjustments to other modules to reflect the overall change to the asset.

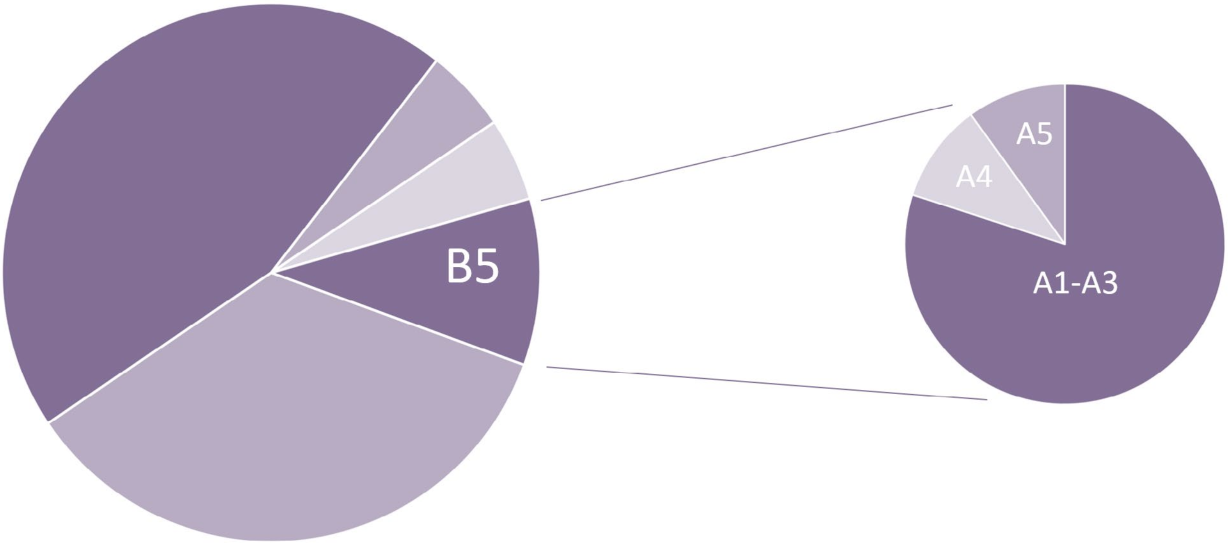


Figure 15: Life cycle stages to be included in B5, with corresponding adjustments to modules B, C and D from the point of change

All impacts arising from the production, transport to site and installation of the components used for a change or refurbishment planned prior to project completion, but undertaken during the in-use stage, must be included in B5.

This also includes any losses during these processes, as well as the carbon associated with any demolition, removal and end-of-life treatment.

Adjustments must also be made to all modules B, C and D in the WLCA from the point of change, in order to accommodate the impact of the altered asset.

Where these changes from alterations or improvements are due to occur, the impact on operational energy will need to be reassessed to calculate the impact on modules B6, B7 and B8. The impacts on maintenance, repair, replacement, demolition/disassembly and disposal will also need to be taken into account. This will then inform the updated WLCA for the built asset, and the new calculations should replace current scenario data.

The consideration of biogenic carbon in B5 must be treated in the same way as for a new project, but note that any net addition or removal of sequestered biogenic carbon from the asset during B5 must be reported separately in the appropriate reporting template.

For more information on the use of the reporting templates, see section 6. See section 4.11.1 for the assessment of biogenic carbon.

For example, if a planned refurbishment in Y30 includes the addition of two additional storeys using a cross-laminated timber (CLT) structure, the net addition of biogenic carbon stored in the CLT will be reported separately in B5. For the decarbonisation of module B5, see section 4.11.5.

5.3 Operational energy use (B6)

This subsection covers carbon emissions from all operational energy use by a building or infrastructure asset over its life cycle, which must be reported in B6.

Operational impacts include all asset-related operational energy use, regulated (B6.1) and unregulated (B6.2 and B6.3), as described in EN15978-1. Any consideration of this breakdown is dependent on the country in which the operational impacts are being calculated. For example, in the UK this breakdown is not considered relevant.

See the reporting templates and Appendix D for a breakdown of energy use.

Annual energy consumption in kWh or equivalent must be converted to carbon using the appropriate carbon conversion factor sets.

Three carbon conversion factor sets should be used when carrying out WLCA calculations, depending on the purpose of the calculations. Refer to Table 9 in section 4.9 and Appendix I for further details.

Requirements concerning decarbonisation are in section 4.11.4, and further details can be found in Appendix G.

For buildings, operational impacts must include all operational energy used in the building, including heating, hot water, cooling, ventilation, lighting, cooking, equipment and lifts, broken down separately by fuel type and energy end use.

The inclusion of any energy use related to external works (e.g. car park lighting) is optional.

When the asset is in the design phase, predictive operational energy modelling should be carried out, and when it is built and in operation, metered data should be used. Figure 16 shows how this should be done.

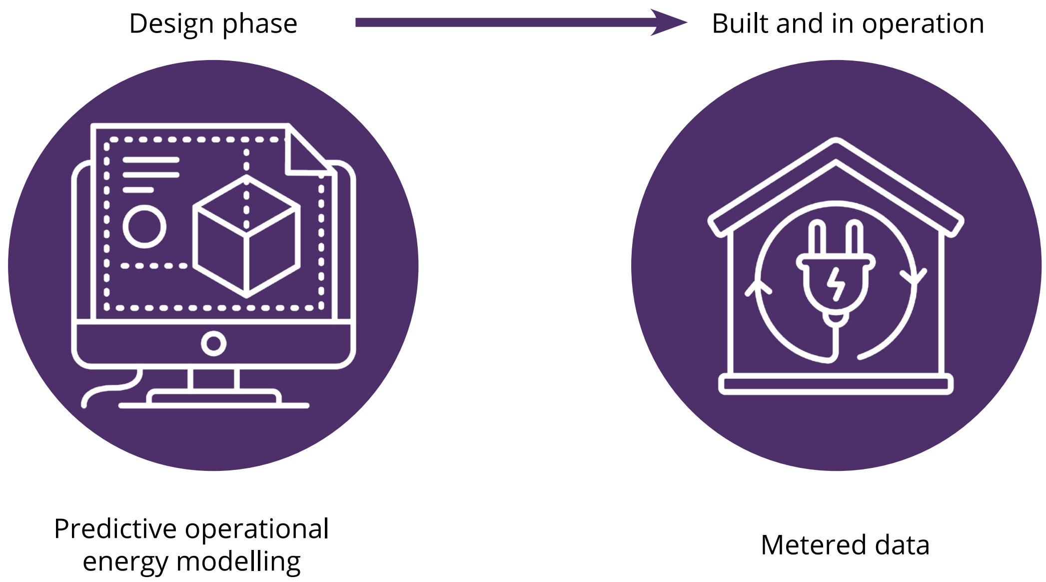


Figure 16: How to calculate operational energy

For infrastructure assets, B6 includes emissions from the energy used to operate the built asset itself and enable its functionality, for example the energy for lighting a road. Emissions arising from the utilisation of the infrastructure asset (e.g. cars driving on a road) and/or the services provided by it (e.g. supplying potable water through water treatment equipment operation) are captured separately under B8; see section 5.5 for more details.

5.3.1 Energy modelling for buildings

Operational energy use predictions should be made by a suitably qualified professional using the guidance outlined either in CIBSE's TM54 Evaluating operational energy performance of buildings at the design stage, NABERS, ASHRAE Standard 90.1, the Passive House Planning Package (PHPP) or a local equivalent operational energy estimation method. These estimates should be refined during each design phase to reduce the levels of uncertainty as more information becomes available.

In the UK, the results of Part L 2021 calculations must not be used under any circumstances, as they are not a prediction of energy consumption.

Where possible, project-specific profiles should be used. Where this is not available, use guidance in CIBSE TM54, NABERS UK or ASHRAE Standard 90.1. For non-residential buildings, sensitivity testing should be carried out to identify the relative effects of different changes and consider the likelihood of different changes in an actual building (e.g. some plant running out of hours), as well as to include the impact of future climate change over the RSP by assessing the design against an appropriate range of future local weather scenarios. Low-end, high-end and mid-range (baseline) scenarios should then be modelled as per CIBSE TM54 or NABERS (off-axis scenarios), with the mid-range (baseline) result being brought forward into the WLC analysis.

The scope must include end uses in Table 21. The 'Energy modelling – typical inc.' tab in the Energy – supplementary tables supporting document outlines how the items included in each reporting category are typically included in energy modelling, and has details on whether they are included in energy usage prediction models such as IESVE Apache SIM, IESVE Apache HVAC, TAS and PHPP. It also outlines how the energy consumption of items that are typically not included in energy modelling can be estimated.

Depending on the design stage, varying levels of detail are required.

- RIBA Stage 1: use benchmarks and/or results from similar projects to show a range of results.
- RIBA Stage 2: model a sample building, or sample floor of a building, to an equivalent degree of accuracy as the details in the design.
- RIBA Stage 3: all buildings in scheme.
- RIBA Stage 4: all buildings in scheme.

The LETI Operational Modelling Guide is a helpful resource for operational energy modelling.

5.3.2 Metering in buildings

Appropriate metering and reporting strategies should be developed in accordance with CIBSE TM39, Building energy metering. Where there is a landlord and tenant relationship, metering should be split between different parties where feasible and reported separately, in line with Table 21. Appendix J provides guidance on how to meter the various energy uses in a building so that they can be reported in line with Table 21, as well as general guidance on energy metering.

A comprehensive metering strategy is important as it is required for fault finding and to understand whether the building services controls are operating as they should. In order to meet the in-use energy consumption that was predicted at the design phase, the controls need to be operating as designed and specified. Many energy inefficiencies found in a building are controls-related, rather than due to the building services equipment itself.

5.3.3 Scope for B6 in buildings

Energy consumption should be reported using the categories in Table 21. For built assets where the assessor wants to investigate energy consumption, it is recommended to report energy consumption in a more detailed format using the more detailed breakdown in the left-hand column, being mindful not to double count.

Measured and predicted operational energy use should be reported separately by fuel type, and energy end use in terms of energy consumption in kWh or equivalent. Where line items in the left-hand column represent large loads, these should be reported separately.

For residential buildings, it is not expected that different energy uses will be sub-metered in-use, only that they are reported separately in the energy predictions. For non-residential all categories should be reported separately both in energy predictions and sub-metered in-use so they can be reported separately in in-use reporting.

Key to Table 21
Minimum requirements for residential buildings; also required for all other building types
Required for all building types, except residential where they are optional

Minimum breakdown for reporting	Scope that must be included in the reporting category
Heating (B6.1)	Space heating consumption (including out-of-hours setback, sometimes called building frost protection). This includes distribution and storage losses.
	Air heating (e.g. heating coil in an air handling unit (AHU)).
	Trace heating and frost protection. This includes energy to keep pipework warm, for example to stop a pipe from freezing or to manage legionella risk, as well as frost protection on an AHU.
	Heat from communal or district heating. Any heat that is exported (generated in the building but used by other buildings) should not be included.
Domestic hot water heating (B6.1)	Domestic hot water heating (including primary and secondary pipework losses, storage losses).
Cooling (B6.1)	Space cooling (including thermal losses).
	Air cooling (e.g. cooling coil in an AHU).
	Heat rejection plant: the energy used to reject the heat (fans and condenser pump) where heat rejection is separate from the compressor (e.g. heat rejection fans at roof level reject heat from a water-cooled chiller).
	Cooling for motor room, plant room, main equipment room, switch room and landlord server room.
	Tenant server room cooling.
	Dehumidification plant.
Mechanical ventilation (including all fans, filtration and heat recovery) (B6.1)	AHUs and mechanical ventilation with heat recovery (MVHR) units (tenant and landlord).
	Fan coil unit (or other terminal unit) fans.
	Exhaust and extract ventilation (landlord).
	Car park ventilation, lift shaft vent fans if used.
Humidification (B6.1)	Humidification plant.

Minimum breakdown for reporting	Scope that must be included in the reporting category
Pumps (B6.1)	Heating: primary, secondary, tertiary pumps.
	Cooling: primary, secondary, tertiary pumps.
	DHW: primary, secondary, tertiary pumps.
	Boosted cold water services, Cat 5 booster set pump energy.
	Sewage pumps (for large projects).
	Rain and grey water, and water treatment pumps.
Lighting (B6.1)	Internal lighting, lighting controls (parasitic load).
	Emergency lighting.
	External lighting, including car park lighting, external signage.
	Other lighting: task lighting, stage/entertainment lighting, display lighting, school sports pitch lighting, retail display lighting, architectural lighting.
Transportation systems in buildings (B6.2)	Lifts (motor, lighting, ventilation, controls, etc.).
	Escalators and moving walks.
Cooking and catering (B6.2)	Cooking (oven, hobs, fryers).
	Refrigeration.
	Dishwashers.
Plug loads (B6.3)	Small power, ICT (not server), cleaners' sockets, vending.
	Washing machines and dryers.
	Plug-in AV and audio systems.

Minimum breakdown for reporting	**Scope that must be included in the reporting category**
Specialist equipment (B6.2)	Servers (serving the buildings).
	Datacentre energy (serving other users/companies/customers).
	Process loads.
	Laboratory equipment.
	Specialist medical equipment in hospitals.
	Pools/spa facilities/hydrotherapy.
	Other, for example facade access cradle.
Security and controls (B6.2)	Controls and building automation.
	Building security systems, CCTV.
	Fire detection and alarm.
	AV and audio systems (hardwired).
	Parasitic equipment loads.
Emergency generator use and maintenance hours (B6.2)	Landlord/life safety generators (energy used for regular testing).
	Tenant generators.
	Diesel pumps, sump heater.
	Uninterruptable power supply (UPS) backup/batteries.
Other uses (B6.1)	Water conditioning and filtration.
On-site generation (generally photovoltaic) (B6.1)	Renewable energy generated that is used on site.
	Renewable energy generated that is exported to the grid, but then re-imported and used over the course of a year.
	Generated renewable energy that is exported to the grid.

Table 21: Energy reporting

The Energy – supplementary tables supporting document outlines how the energy consumption results of predicted modelling should be reported, which items should be included in each reporting category, whether they are typically included in energy modelling, and details on whether they are included in energy usage prediction models such as IESVE Apache SIM, IESVE Apache HVAC, TAS and PHPP. It also outlines how the energy consumption of items that are typically not included in energy modelling can be estimated.

5.3.4 Electric vehicles

Where electric vehicle charging points are provided, these should be sub-metered and reported separately in B8.1; they are not included as part of B6.

5.3.5 District heating

The carbon emissions associated with the heating provided by any district heating scheme are accounted for in B6, including any losses in the scheme. More information on this can be found in Appendix H.

5.3.6 Energy from renewables

Energy from onsite renewables and the electricity grid must be reported separately. Refer to Appendix H.

5.3.7 Operational energy use for infrastructure assets

Energy used for processes required to support the operation of the infrastructure built asset itself should be included in B6, such as lighting for a motorway. The energy use should be broken down by purpose and source of energy (electricity, fuel, etc.).

Any energy use controlled by the operator of the infrastructure asset and associated with the core function, over and above the operation of the infrastructure built asset itself, should be covered in B8, such as emissions from industrial machinery in a water treatment plant. B8 is also used to report the impacts of users of the infrastructure, for example vehicles on a road or planes on a runway.

5.4 Operational water use (B7)

This section covers the carbon impacts from water use during the operation of the built asset over its life cycle.

All carbon impacts related to water supply and wastewater treatment, as measured and/or predicted over the life cycle of the asset (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. pumping boosted cold water, onsite wastewater treatment or the energy used to heat water) should be captured under module B6.

Any impacts associated with materials used as part of the normal operating of any water service system in the building during the in-use stage are covered in B7 (e.g. filters, salt and chemicals). This does not include elements in the building element categories such as pipes, fittings and pumps; these are included in A1–A5 (and if relevant B2–B5).

Operational water use should be reported as water consumption in m^3 by type (treated water, ground water, grey water, etc.) and then converted into carbon emissions using appropriate emissions factors for both water supply and wastewater treatment. If no other data is available, it should be assumed that the amount of water consumed is treated. Carbon conversion factors for mains water provision and offsite treatment 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 section 4.9).

Where relevant, B7 should cover the following:

B7.1 Water used by integrated systems	B7.2 Water used by other integrated systems	B7.3 Water used by non-integrated systems
Water for sanitation, cooking and drinking; irrigation of associated landscape areas, green roofs and walls; and heating, cooling, ventilation and humidification systems.	Such as fountains, swimming pools and saunas.	Such as for dishwashers, washing machines and washing cars.

Figure 17: Sub-modules of module B7

When built assets, new or refurbished, are being designed, it is possible to predict their potential operational water use for a range of operating conditions. Predictions should be reported as a range in accordance with their level of uncertainty, which will be higher for buildings where the end users are unknown.

Predictions of anticipated water consumption should be made by suitably qualified public health engineers using the guidance in CIBSE Guide G, Public health and plumbing engineering or in the Institute of Plumbing's Plumbing Engineering Services Design Guide.

For simple buildings where this is not possible, the maximum daily water consumption values from the latest version of the BSRIA Rules of Thumb – Guidelines for the building services can be used for the respective building types. These predictions should be refined during each design phase as more information becomes available, in order to reduce the levels of uncertainty.

5.5 User activities (B8)

Quantification of the impacts from user activities related to the asset under assessment is optional, and the information in module B8 constitutes additional information in the WLCA. Any explicit requirement to assess impacts from user activities would typically depend on the nature of the project and/or the specific assessment brief.

5.5.1 User activities in buildings

B8 covers impacts associated with user activities taking place during the operation of buildings that are not covered by B1–B7. These can include:

B8.1 Energy-related impacts associated with building user mobility/transport not covered in B6, such as user mobility/commuting to a building (optional)

(+)

B8.2 Energy-related impacts associated with building user charging of electric vehicles on-site (optional)

(+)

B8.3 Other energy-related impacts associated with building user activities relating to the building's intended use, such as upstream embodied impacts of consumables used in the building, e.g. stationery and printing paper for an office (optional)

Figure 18: Sub-modules of B8 for buildings

For transport of persons to and from the building (B8.1), estimation of such impacts may be useful for strategic decision-making in certain cases. For instance, it could be part of the wider systems thinking about carbon management suggested in PAS 2080, or when deciding the location of an office development on a greenfield or urban site.

Guidance documents such as GHG Protocol Technical Guidance for Calculating Scope 3 Emissions, chapter 7 provide information on how these emissions can be calculated. See section 4.8 for the emissions factors to be used.

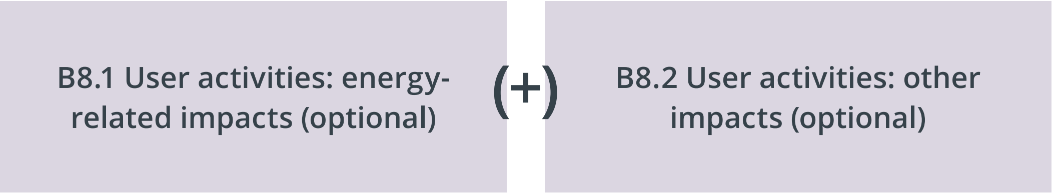
5.5.2 User activities in infrastructure assets/civil engineering works

While the main purpose of buildings tends to be to house people so that they are able to effectively perform their activities, infrastructure assets are typically built to enable a specific function or process – the 'service' – such as transportation of goods and/or people, energy generation, or treatment of water or waste.

This concept can help distinguish between energy-related impacts from the operation of the infrastructure built asset itself – the ‘shell’ (captured in B6 and B7) – and the impacts originating from processes required to provide the service and the activities undertaken by its users (captured in B8), as the boundary between ‘shell’ and ‘service’ can be difficult to establish.

Therefore, for buildings where operation of the built asset itself is the main function, most of the energy impact is expected to sit under B6. For infrastructure, where the built asset itself may only provide the shell to house highly energy-intensive activities run by its users/operators, significant impacts can be expected to arise from the asset’s utilisation. These need to be captured in B8.

On this basis, the structure of B8 for infrastructure assets is different from that of buildings and can be split as follows:



B8.1 User activities: energy-related impacts (optional) (+) **B8.2 User activities: other impacts (optional)**

Figure 19: Sub-modules of module B8 for infrastructure

Any impacts arising from energy consumption for processes required to support the operation of the infrastructure built asset itself – the shell – should be included in B6, such as lighting for a motorway. Any impacts associated with energy consumption to fulfil the asset’s function, including necessary activities/processes as well as the use of the infrastructure by stakeholders – the service – over and above the operation of the shell, should be captured in B8.1. This may include impacts from vehicles driving on a motorway, fuel use at a power-generation plant, planes using a runway or the operation of industrial machinery at a water treatment plant.

Any non-energy-related impacts, such as from chemical processes taking place in systems within infrastructure assets, should be captured in B8.2. These could include carbon emissions or removals from chemical reactions as part of manufacturing processes such as limestone calcination at a cement production facility, fossil fuel refining at an oil refinery, or chemical products used in water treatment systems in a wastewater treatment works.

For utilities produced by infrastructure assets, such as energy generated by power stations or potable water from water treatment plants, the amount of such utilities exported from the asset should be reported under B8, and any benefits or loads associated with their use should be reported under D2.

If deemed relevant, impacts relating to user activities for any buildings forming part of a wider infrastructure asset/project can be captured using the B8 structure for buildings; see section 5.5.1.

5.6 End-of-life stage (C1–C4)

The end-of-life stage begins when the built asset has reached the end of the RSP, as defined in section 4.2. The asset may continue to be used in another RSP, with or without refurbishment, or it may be decommissioned for deconstruction and/or demolition. Parts of the asset, for example MEP systems, may reach the end of their service life before the overall asset and will need replacing (see section 5.2.4).

Module C impacts must be included for all components and materials that make up an asset at the end of the RSP, whether the asset continues to provide functionality or not. Any impacts arising from decommissioning, stripping out, disassembly, deconstruction and demolition operations, as well as from transport, waste processing and disposal of materials at the end of life of the project, must also be accounted for in module C.

All components and materials leaving the building are first considered waste. The end-of-life stage is considered complete within the scope of a WLCA when all end-of-life processes have been completed for all components and materials leaving the building, including any associated collection, sorting, transport and waste processing, and the waste has reached the ‘end-of-waste’ state. This is defined as the point when waste has been recovered so that:

- it is commonly used for specific purposes
- a market or demand exists for it
- it fulfils technical requirements and meets the existing legislation and standards applicable to products, or
- its use will not lead to overall adverse environmental or human health impacts.

Table 22 illustrates the end-of-life processes, the various end-of-life routes for each process, the life cycle module they are considered in, their outputs and how they are considered in D1.

End-of-life process	End-of-life route	Module	Output flow	Loads and benefits
Reuse	Reuse on-site	C3	Material for reuse	Net output flow of material for reuse in module D1
	Reuse offsite without preparation for reuse required	C3		
Recovery	Reuse with preparation for reuse	C3		
	Recycling	C3	Secondary material	Net output flow of secondary material in module D1
	Other recovery, e.g. composting, backfill	C3		
	Recovery as secondary fuel	C3	Secondary fuel	Output flow in module D1
	Energy recovery (with R1 status)	C3	Exported energy	
Disposal	Landfilling (including use of captured landfill gas)	C4		
	Incineration (without R1 status)	C4		

Table 22: End-of-life processes and routes

Table 22 presents end-of-life processes in the order of preference to retain value and mitigate carbon impacts. While a range of routes are presented, there will be material- and product-specific routes that impact on the value and functional equivalence of materials where recovered. For the purposes of assessing end-of-life scenarios, the following definitions should be used, developed from BS EN 15978:2011.

- **Reuse**: any operation through which products or components that are not waste are used again without reprocessing. An example would be a timber beam being reused as a timber beam.
- **Recycling**: Any recovery operation by which waste materials are reprocessed into products, materials or substances, either for the original purpose or for other purposes. It should be noted that within recycling, there are two main routes:
  - **Closed loop recycling**, where the discarded product is recycled into an item of functional equivalence to the original, without changing its inherent properties, such as a steel beam being recycled into a new steel beam.
  - **Open loop recycling**, where the discarded product is recycled into a different one, altering its physical nature. This usually means being downgraded to a product of lower quality and/or value, such as a concrete beam being crushed to be recycled as aggregate or fill.

Therefore, while reuse and recycling rates are provided in subsequent sections, it is important to understand the material-specific details for a given project. This is crucial to understand when considering any benefits and loads in module D; see section 5.7.

5.6.1 End-of-life scenarios

The assessor should develop suitable project-specific end-of-life scenarios at the asset level, as well as the individual component and material level where relevant, based on future intentions provided by the project team, precedent and current end-of-life practices. **The end-of-life scenarios must be clearly stated and explained in the WLCA report.**

The proportions allocated in the WLCA at the design, construction and post-completion stages to various reuse, recycling, other recovery or disposal end-of-life routes for different materials and components must be supported by verifiable and project-specific documentation if they vary from the 'business as usual' (BAU) end-of-life routes set out in Table 22 for the UK.

Assessments in other countries may use these default figures but should use national equivalents if available; the assessment should then make clear what source has been used.

Table 23 provides detailed UK BAU percentages for WLC assessors and design teams to use for the various end-of-life routes applicable to the most common materials used in construction. Current practice and technology should be assumed for the default BAU case, with any other scenarios requiring justification from the design team.

Material	Details	Default end-of-life routes			
		Reuse	Recycling	Incineration with/ without energy from waste	Disposal (landfill and losses)
Concrete[1]	Cast in situ	0%	97.5%	0%	2.5%
	Precast[2]	<1%	96.5%	0%	2.5%
Steel[3]	Hot-rolled structural sections, including plate and tubes	7%	93%	0%	0%
	Light gauge galvanised steelwork, e.g. studwork, cladding framing	5%	93%	0%	2%
	Piles (sheet or bearing)	15%	71%	0%	14%
	Rebar[4]	0%	98%	0%	2%

Material	Details	Default end-of-life routes			
		Reuse	Recycling	Incineration with/ without energy from waste	Disposal (landfill and losses)
Masonry[1]	Blockwork	0%	97.5%	0%	2.5%
	Brickwork[5]	<1%	97.5%	0%	2.5%
Timber[6]	Solid timber (untreated, uncoated)	<1%	78%	20%	1%
	Treated, coated timber (non-hazardous)	0%	30%	69%	1%
	Engineered timber (CLT, glulam, etc.)	5%	35%	59%	1%
	Wood-panel products	0%	0%	99%	1%
Aluminium[7]	Sheet	0%	96%	0%	4%
	Profile	<1%	96%	0%	4%
Plasterboard[8]	General	<1%	17%	0%	83%
Glass[8]	All types	0%	61%	0%	39%
Plastics[8]	All types			100%	
Coatings[8]	Paints, intumescent coatings, cementitious sprays	0%	0%	0%	100%
Insulation[8]	Mineral-based		<1%		99%
	Hydrocarbon-based			95%	5%
	Biobased[9]			95%	5%
Asphalt[1]	All types	0%	97.5%	0%	2.5%
Unbound aggregate[1]	All types	0%	97.5%	0%	2.5%
Soils[1]	Includes topsoil and inert non-hazardous earth	0%	97.5%	0%	2.5%

Material	Details	Default end-of-life routes			
		Reuse	Recycling	Incineration with/ without energy from waste	Disposal (landfill and losses)
MEP equipment[10]	Heat-generation equipment	0%	70%	0%	30%
	Pipes	0%	90%	0%	10%
	Lights	0%	45%	0%	55%
	Ventilation system	0%	40%	0%	60%
	Radiators	0%	80%	0%	20%
	Wire cables	0%	50%	0%	50%

Table 23: Default BAU end-of-life scenarios at the material level for the UK, by percentage mass

Notes on Table 23

[1] Figures based on mineral waste from construction, demolition and excavation – UK government waste statistics.

[2] There is no distinction of precast concrete in the waste statistics, but small quantities of precast concrete are reused, for example in structural planks and paving.

[3] Steel figures from Engineering Sustainability Volume 167 Issue ES3 Briefing: Reuse and recycling rates of UK steel demolition arisings, June 2014.

[4] Rebar may be reused as part of a reused foundation, but rebar losses can also be greater in substructure applications.

[5] There is no distinction of lime mortar in brickwork, but brickwork and stonework are reclaimed for reuse. The assessor should exercise judgement based on the proposed specification.

[6] Figures from Assessing the carbon-related impacts and benefits of timber in construction products and buildings, technical paper, November 2021.

[7] prEN 17662:2021 Execution of steel structures and aluminium structures - Environmental Product Declarations - Product category rules complementary to EN 15804 for Steel, Iron and Aluminium structural products for use in construction works.

[8] BRE Global Product Category Rules (PCR) For Type III EPD of Construction Products to EN 15804+A2 PN 514 Rev 3.0.

[9] Assume that biobased insulants would follow same end-of-life scenario, unless other data is available.

[10] CIBSE TM65.

Where end-of-life intentions are unclear or being investigated by the design team, assessors should consider a range of scenarios based on likely activities at the end of the RSP. These scenarios should themselves consider the proportion of reuse, recycling and disposal. Table 24 provides examples of scenarios that may be considered, covering opportunities to improve on BAU with current technology.

Scenario	Description	Reuse	Recycling	Disposal (landfill, incineration and EfW)
Business as usual	Baseline scenario where no effort has been made to improve deconstruction or recovery potential.	See default rates by material in Table 23.		
Good practice	Deconstruction and recovery are actively considered by the design team and captured in design information to be retained by the client. The design team must be able to justify reuse levels for specific materials with verifiable documentation.	25%	70%	5%
Best practice	Deconstruction and recovery are key drivers of design and promoted by the client. Materials or components that cannot be currently recovered or recycled are avoided. The design team must be able to justify reuse levels for specific materials with verifiable documentation.	50%	50%	<1%

Table 24: Example end-of-life scenarios at aggregated asset level by percentage mass

These reflect aggregated ambition levels and should be broken down by material and products as appropriate, as different materials will have different end-of-life BAU routes, with different proportions going to landfill or reuse. For example, structural steel is already highly recycled and the BAU recycling and reuse percentage is already greater than 90%, so good practice and best practice reuse rates for steel would need to be adapted upward accordingly. If the disposal rate for good or best practice is higher than the BAU rate for a material provided in Table 23, use the BAU rate and adjust the recycling rate accordingly.

However, good design and detailing, and correct installation and maintenance, are required to ensure that the materials and components are in a suitable condition to enable reuse or recycling. Wherever possible, a detailed project-specific scenario should be developed with project data. **Designers must demonstrate a credible deconstruction and recovery strategy using current technology to increase the end-of-life scenario percentages from the default BAU percentages.** Examples could be the use of lime mortar to enable masonry recovery, or the use of accessible mechanical connections to allow future deconstruction. ISO 20887 provides detailed guidance on design for deconstruction.

Impacts for modules C1 and C2 should also be adjusted to reflect any change from BAU practice; see sections 5.6.2 and 5.6.3.

Data for modules C1–C4 from EPDs and other carbon data sources should only be used in line with the project-specific end-of-life scenarios developed. Decarbonisation could have a significant impact on the calculation of modules C and D. This is primarily because RSPs are 60 or 120 years (in the UK, but may vary in other countries). This takes end-of-life considerations into the 2070s and beyond, a point at which many governments and industries have committed to being net zero. Processes such as energy from waste cannot be decarbonised except through the use of carbon capture, which will require a significant additional input of energy that will affect efficiency. For biogenic carbon, permanent capture cannot be modelled. The transfer of biogenic carbon with reuse or recycling to the next product system also cannot be decarbonised.

Therefore, modules C3 and C4 must not be decarbonised. Modules C1 and C2 can be decarbonised in accordance with section 4.11.5.

5.6.2 Deconstruction and demolition impacts (C1)

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

The impacts arising from any on- or offsite deconstruction and demolition activities at the end of life of the asset, including any energy consumption for site accommodation and plant use, must be considered in C1.

Where there are building or infrastructure elements such as foundations, pipes, cables or ducts within 3m of ground level, the removal and disposal of these items must be accounted for, even if their removal is not anticipated within or at the end of life of the assessed asset.

If the asset includes underground voids, tunnels or basement structures more than 3m below ground that would not be practically anticipated to be removed, then any stabilisation works required to make them safe must be accounted for in C1, for example by filling belowground tanks with an inert compacted material.

Module C1 values can vary significantly, depending on the end-of-life scenario being considered. Generally, this is linked to the work required for deconstruction or demolition. Where module C1 values are being taken from EPDs, it is important to confirm which end-of-life scenario and end-of-life routes are assumed. Where there is a disparity between the EPD and project end-of-life scenario, a reasonable adjustment should be made, noting the following guidance to assist the assessor.

Where no other information is available, the C1 impacts for a given asset should be treated as a proportion of the A5.2 impacts from construction activities. Where no specific measures have been taken to improve end-of-life recovery, the recommended BAU proportions are as indicated in Table 25. Where the design team has demonstrated that design for disassembly and recovery has been incorporated, the assessor should make a reasonable adjustment to these figures to reflect an increased rate of recovery.

Scenario	Impact on C1	Recommended percentage of A5.2
Business as usual	Standard practice for demolition, minimal attempt at deconstruction and recovery	25%
Good practice	Deconstruction carried out to recover key elements/ materials for reuse	30%
Best practice	Deconstruction carried out to recover a majority of elements and materials for reuse	50+%

Table 25: C1 values as a proportion of A5.2, to be adjusted after reporting to allow for appropriate grid decarbonisation at assumed date of recovery

Where materials are prepared for reuse or recycled on site, impacts should be reported in C3.

Refrigerant leakage impact when decommissioning the systems at end of life (following the CIBSE TM65 methodology) should be accounted for in C1. This is in addition to impacts associated with general deconstruction/demolition activity.

5.6.3 Transport impacts (C2)

Any carbon impacts associated with the transportation of material from deconstruction and demolition to the appropriate final location, including any interim stations, must be captured in module C2.

In general, the transport impacts should be calculated based on the following formula:

> C2 = mass of material or product (a) x transport distance (b) x [carbon conversion factor outward (c2) + (empty running factor x carbon conversion factor return (c1))]

See section 5.1.3 for definitions of (c1), (c2) and empty running factor.

The default distance to be used in the absence of specific information should be the average distance from the two closest reclamation/waste processing facilities/landfills to the project site. The mode of transportation that should be assumed is an average rigid HGV with 50% load, to account for the vehicles coming to site empty and leaving with 100% load.

For items being recovered, default transport scenarios to be used in the absence of more specific information are given in Table 26.

End of life scenario	Transport scenario
Reuse/recycling on site	No transport impacts; C2 = 0
Reuse/recycling elsewhere	Average distance to two closest construction waste processing sites
Energy recovery/ incineration	Average distance to two closest energy-from-waste sites
Landfill	Average distance to two closest landfill sites

Table 26: Default transport assumptions for different end-of-life scenarios

For MEP products when no EPDs are available, follow the CIBSE TM65 methodology and local addendum assumptions if outside the UK.

5.6.4 Waste processing for reuse, recycling or other recovery (C3)

When materials and/or components are intended to be reused, recycled or recovered after the RSP of the asset, any impacts associated with their preparation for reuse, waste treatment and recovery prior to reaching the end-of-waste state must be included in module C3.

The calculation of C3 should follow the end-of-life scenarios developed by the assessor for each item. Data for C3 from relevant EPDs should be used, adjusted to suit the selected end-of-life scenario. In the absence of specific information regarding the waste processing for items leaving the asset, the default emissions for disposal to landfill should be applied (see section 5.6.3).

Where materials are incinerated with energy recovery, the emissions should be recorded in C3. Energy recovery can only be considered where incinerators meet R1 status (where waste-to-energy incinerators meet the required Energy Efficiency Formula standard according to the Waste Framework Directive: 65% post-2008 and 60% beforehand). If it is not likely that the materials would be incinerated in an R1 facility, incineration should be treated as a disposal activity and reported in C4. Alternatively in the UK, for simplicity, use the following generic data for energy from waste in the UK and report it in C3.

Energy from waste type	Metric	Electricity output	Heat output
Biomass using recycled wood (Tolvik 2019)	Per tonne of waste wood*	880kWh	0
Energy from waste – not biomass (Tolvik 2020)	Per tonne of waste	560kWh	150kWh
	Per GJ net calorific value (NCV)*	61kWh	16kWh

Table 27: Generic energy from waste data for the UK

* This gives a typical actual efficiency of UK energy from waste plants using biomass of approximately 18%, and of 28% for energy from waste plants using other fuels, slightly below the standard required to achieve R1 status.

Assessments in other countries may use these default figures but should use national equivalents if available; the assessment should then make clear what source has been used.

See section 4.11.1 for information on how to report the transfer or emission of biogenic carbon in biobased materials considered in C3.

The types of activities undertaken as preparation for reuse in module C3 include:

- removal of coatings from timber and steel, including their disposal
- removal of mortar from bricks and masonry, including its recovery, and
- removal of joints and fixings from structural steel, including their recovery.

For material that is recycled, the end-of-waste state varies.

- For metals, it is when they have been collected as separate scrap metals.
- For concrete, masonry, stone and ceramics, it is when all components, materials and waste are processed/crushed and cleared from site, or repurposed as part of the site's reinstatement.
- For glass, it is when it has been crushed for use as cullet.
- For plastics, it is when they have been granulated.
- For timber, it is when it has been chipped for recycling or use as secondary fuel.
- For MEP products where no EPDs are available, follow the CIBSE TM65 methodology and local addendum assumptions if outside the UK.

5.6.5 Disposal impacts (C4)

Module C4 captures impacts resulting from any processing required prior to disposal and from the degradation of landfilled materials, or incineration without energy recovery or in a plant without R1 status (Energy Efficiency Formula standard, according to the Waste Framework Directive, less than 65%). This is only applicable for items not being recovered for reuse, recycling or other recovery.

For elements not expected to be reused, recycled or recovered, but intended for final disposal either in landfill or incineration, an allowance for the impacts from their disposal must be included in C4.

The calculation of C4 should follow the end-of-life scenarios developed by the assessor for each item. C4 data from relevant EPDs should be used, adjusted to suit the selected end-of-life scenario. Where data for disposal is unavailable, default assumptions should be used. The default figures should utilise the most current government GHG conversion factors for company reporting. Table 28 refers to 2022 figures for UK construction waste to landfill.

Assessments in other countries may use these default figures but should use national equivalents if available; the assessment should then make clear what source has been used.

Material	kgCO_2e per tonne
Aggregates, asphalt, masonry, concrete	1.234
Metals	1.264
Asbestos	5.913
Soils	17.577
Plasterboard	71.950
Timber	828.014

Table 28: Default impacts figures for waste to landfill

For biobased materials, see section 4.11.1 for information on how to account for sequestered biogenic carbon in C4.

The impacts associated with incineration of waste where the facilities do not have recovery status (R1) should be reported in C4. Potential energy recovery from waste incineration and landfill gas should be captured in module D.

For MEP products where no EPDs are available, follow the CIBSE TM65 methodology and local addendum assumptions if outside the UK.

5.7 Benefits and loads beyond the system boundary (D1 and D2)

Module D is reported as two separate sub-modules.

- **Module D1**: potential benefits and loads from reuse, recycling and energy recovery from the net output flows of materials exiting the system boundary, and/or from other recovery (e.g. from incineration or from use of captured landfill gas).
- **Module D2**: potential benefits and loads from exported utilities exiting the system boundary.

5.7.1 Module D1

Module D1 covers the potential loads and benefits from reusing or recycling materials and components at end of life, or from any energy recovered from them at end of life (e.g. energy from waste, incineration or use of captured landfill gas). Module D1 is relevant to any end-of-life output from the asset during construction (module A5); maintenance, repair, replacement and refurbishment (modules B2–B5); and from waste treatment and disposal (modules C3 and C4). It also includes loads and benefits associated with the deconstruction/demolition activities of existing assets on the site, assessed in module A5.1.

What is modelled in module D is therefore directly related to the end-of-life routes used in module C and must align with them.

The calculation of D1 is set out in EN 15804 and adopts a net flow methodology. This methodology seeks to avoid double counting the benefits of reused and recycled materials in both modules A1–A3 and module D1. **As reused and recycled material is considered to enter the system with no impact from its previous use, recovered outputs of end-of-life material in modules A4–A5, B2–B5 and C3–C4 must have the input flows deducted from the output flow to avoid double counting.** Only if there is a net output flow of a reused material or secondary material from the asset over the RSP is this net output considered in module D1, as shown in Figure 20.

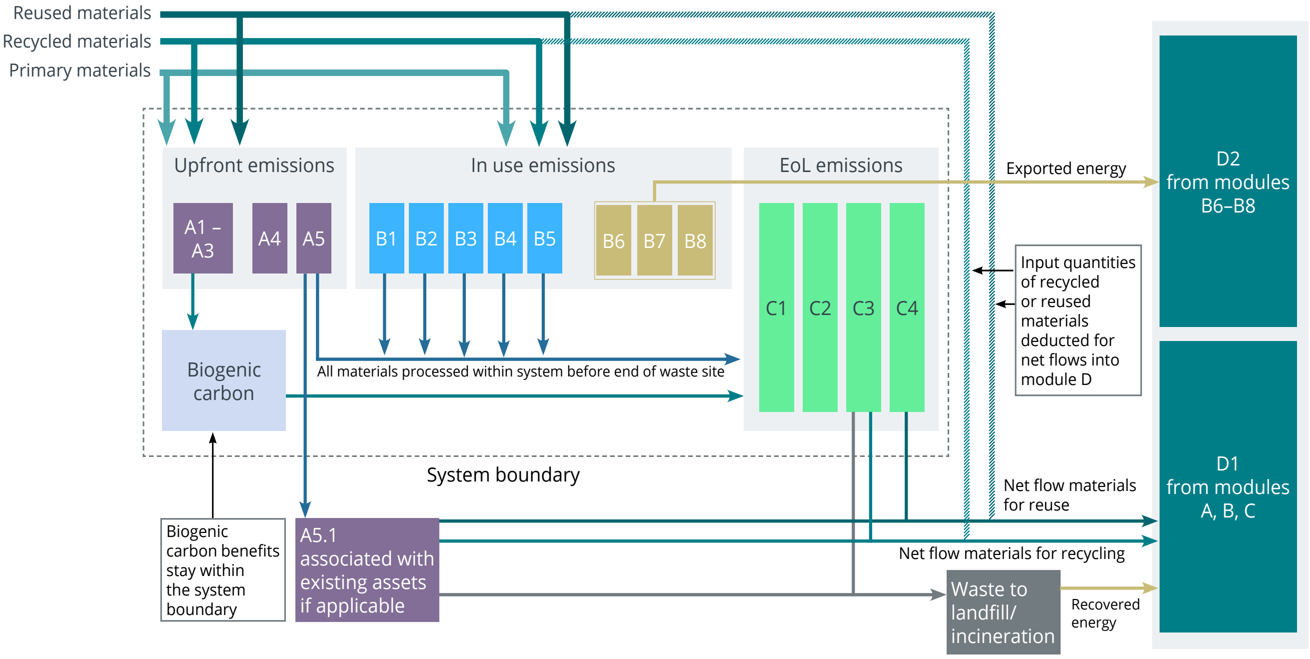


Figure 20: Flow of materials and emissions between modules

For each relevant module, redundant material can either be disposed of or recovered. This choice depends on the scenario, as well as the quality of the design and detailing of the proposed asset.

For any net output flows, and for recovered energy flows from recovery and disposal processes, D1 shows the value of these flows when they substitute primary material or energy production by modelling the loads of any processing to reach the point of substitution, and the benefit of avoiding things such as primary material production or grid electricity.

Module D1 is intended to provide a broader picture of the environmental impacts of a project by accounting for the future potential of any primary materials used when these are recovered, for example if they are reused and/or recycled.

The total D1 calculation is specific to the project being assessed. There is no actual numerical transfer of loads or benefits to another project. Instead, it is a supplementary figure that indicates the future potential for recovery from net output flows that has been incorporated into the current project. Module D1 has some potential to be used as a metric for quantifying circularity and assessing future resource efficiency, but also has limitations. For example, a building made of recycled products that are recycled at end of life would show no benefit in D1 because the outputs of secondary material at end of life would all loop to the inputs of secondary material in the recycled material, and there would be no net output to D1. The avoided burdens of primary production in D1 are also modelled on current production impacts, as are replacements in B4, but as we expect materials and energy production to decarbonise (see section 4.11.4), so we also expect the loads and benefits in D1 to decarbonise.

Any decarbonisation strategy used must also be applied to the loads and benefits of reused and secondary material and recovered energy in D1.

The net output flow represents the net addition of primary materials into secondary use. It is calculated by considering any output flows of a given secondary material or secondary fuel and subtracting any input flows of the same secondary material or secondary fuel, as indicated in Figure 21.

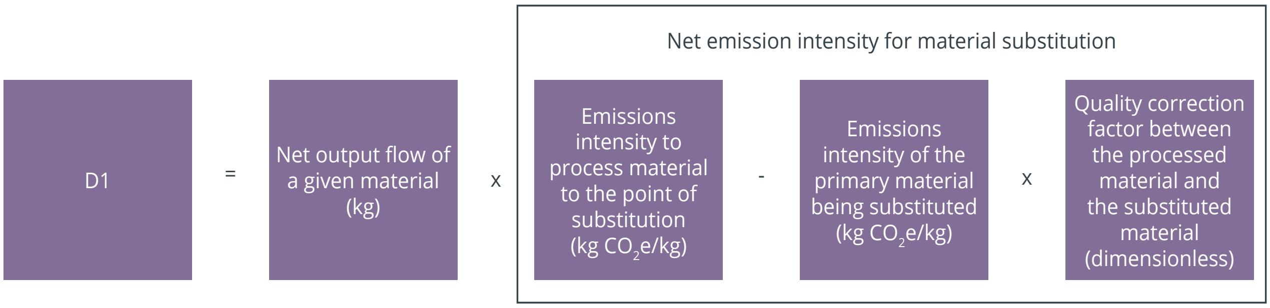


Figure 21: Calculating carbon in module D1 for a material

Reused materials and secondary materials should be considered as different materials, so an output of a given reused material would not need to deduct an input of the same secondary material, only an input of the same reused material. However, for an output of recycled material, any input of the same recycled or reused secondary material should be considered in calculating the net output flow.

The impacts of any processes required to process a net output flow after leaving the system boundary (the end of waste state) to reach the 'point of substitution' (where reused or secondary material or secondary fuel is substituted for primary production), and recovered energy, e.g. electricity is substituted for grid energy, must also be calculated to establish the 'loads' in the benefits and loads beyond the system boundary considered by module D1.

Module D1 is calculated by subtracting the impacts of the substituted primary production (the 'benefits') from the 'loads' (the impacts to reach the point of substitution). The impacts of substituted primary production will be significantly affected by the decarbonisation approach taken in a WLCA.

A value correction factor reflects any difference in functional equivalence or quality of the secondary product as a result of the recycling/reuse process, compared to that of the equivalent substituted primary material.

Energy recovered from materials beyond the end-of-waste state (e.g. from timber or plastics used in waste for energy plants (C3) or incinerated (C4), or from recovery of landfill gas from biobased waste) should be accounted for in D1. Energy recovery calculations should be conducted based on the net calorific value of the material, and the typical types and quantities of energy recovered (see section 5.6.4). The type of energy substituted (grid electricity or gas) should be determined based on reasonable assumptions, applicable to local practices, that enable realistic estimations of the carbon impacts avoided by the energy displaced.

For the treatment of biogenic carbon in module D, see section 4.11.1 and the example in Appendix K.

The impact of module D1 should be considered for every item that a reuse, recycling, recovery or disposal scenario has been developed for. Therefore, for components being replaced (B4) multiple times over the life cycle of the project, D1 should be accounted for each time the item is replaced and the redundant component is intended to be recovered.

The detailed calculation approach from EN 15804:2012+A2:2019 and examples to illustrate D1 calculations for different materials and end-of-life destinations for steel, timber and concrete are set out in Appendix K.

Module D1 must be communicated separately, as it mainly occurs beyond the RSP and outside the system boundary of the project being assessed, and also includes inherent uncertainty regarding the future treatment of building components.

However, it is important to assess module D1 as well as A–C, in order to acquire a more holistic understanding of the environmental impacts of an asset. This takes potential future benefits or loads into account and promotes thinking about the future, encouraging connectivity between current and future projects.

Project-specific scenarios for the intended/expected future handling of items beyond the end of life of the project, at the asset and/or component level, should be developed and substantiated as appropriate. These are based on supporting information provided by the project team and the anticipated supply chain. The scenarios should be realistic, feasible and capable of third-party verification.

Different scenarios can be developed for the same project concerning the future reuse, recycling and recovery of items beyond the end of life, but this will require the same evidence for alteration of the default BAU end-of-life scenarios as set out in section 5.6.1, and the modelling of altered scenarios for C1–C4 as relevant. Each scenario will therefore result in a different value for C1–C4 and D1, and each should be presented clearly and explained in the WLCA report, with an indication of its likelihood.

Depending on the extent of reuse and/or recycling anticipated, appropriate boundaries for the potential loads and benefits should be determined according to where the point of substitution is expected to be for each scenario. Reuse/recycling activities can range from the full reuse of an item as is (e.g. retained structural frame) to individual component reuse (e.g. steel sections or cladding modules) or material recycling (e.g. glass cullet from discarded windows or concrete crushed into aggregate).

When full reuse of components in their exact assembled state is anticipated in the future (e.g. in a refurbishment), the impacts from the construction stage (A5) would be reduced due to any avoided deconstruction, transport and disposal impacts (C1, C2 and C4), as well as avoiding future product, transport and construction impacts (A1–A5) for the retained elements. For individual element reuse, when this is expected to occur on-site, the offset of product stage (A1–A3) and transport (A4) carbon impacts can be claimed. For all other instances where offsite reuse and/or recycling are anticipated, the scope of the impacts to be taken into account in D1 should be limited to the product stage (A1–A3).

Module D1 data should be derived from appropriate sources (see section 4.8) in accordance with the project-specific scenarios developed. The assumptions made to estimate the D1 figures in the selected sources should be checked against the project-specific ones developed by the assessor. If different, the D1 values should be adjusted to fit the project-specific scenarios. For example, if an EPD for precast concrete panels assumes recycling (downcycling) of the disposed items via crushing into aggregate, but the project-specific scenario anticipates the reuse of the discarded panels elsewhere rather than crushing, the D1 figures should be adapted to reflect the reuse scenario for the project.

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

While D1 can provide an insight into potential avoided impacts, it may not provide a true reflection of circularity benefits at the end of the RSP, particularly where there are significant secondary material inputs. It is therefore recommended that assessors make design teams aware of the limitations of a net flow methodology and consider using complementary metrics or methods to assess circularity benefits.

For example, additional scenarios taking into account the **total** material flows exiting the system, rather than the net flows (i.e. primary only), could be developed. These need to be clearly indicated and reported separately from module D. This approach (total flows) is expected to provide a clearer picture of the benefits that could accrue from reusing, recycling or recovering building components and help drive decision-making towards a more circular economy.

5.7.2 Module D2

If a building generates more energy than it uses over the course of the year, this ‘exported’ energy is reported as part of module B6 for buildings (see Appendix G2). For infrastructure that generates energy or produces other utilities, these are reported as exported utilities as part of B8. For both buildings and infrastructure assets, any benefit from these exported utilities (e.g. the avoided impact of grid electricity generation for exported electricity) is reported in D2. For more information, refer to Appendix G.

All data in D2 should be decarbonised using the same decarbonisation scenarios used for energy in B6.

D2 must be communicated separately from the impacts of modules A1–C4, as it shows the benefits of the project outside the system boundary.

6 Reporting requirements for WLCAs

This section specifies the information and assumptions that must be disclosed as part of a full WLCA report. It provides a recommended reporting structure, identifying the purpose of each reporting template and how it can be used for differing asset types, alongside specifying the units of measurement to be reported. It concludes by stating how WLCAs must be communicated to third parties, where required.

6.1 General guidance for reporting

Varying levels of detail are expected to be available at different phases of construction projects. Therefore, minimum reporting requirements of progressively increasing detail are mandated in line with key phases of project progress: early design, technical design and post-project completion. Greater aggregation and a less-detailed breakdown of carbon results is allowed at early phases, although it is still best practice to report the highest level of detail possible.

The following reporting templates are provided on the RICS website:

- Reporting template – summary: summary reporting at the project level.
- Reporting template – buildings: reporting per element category, by life cycle stage and at asset/sub-asset level for building projects.
- Reporting template – infrastructure: reporting per element category and by life cycle stage for infrastructure assets/civil engineering works.

Reporting template – summary **must be used to report WLCA results for all assessments. The summary is populated using data from** Reporting template – buildings **and/or** Reporting template – infrastructure**, depending on the sub-assets included in the project being reported.**

Further detail is provided in section 6.2.1 and Table 29.

A full WLCA report must contain the mandatory information detailed in this section.

It is strongly recommended to include the optional information.

All asset elements and life cycle stages (modules A–C, and module D separately), must be reported in order for the WLCA to be fully compliant with this standard.

It is expected that the outputs of WLCAs should be entered into the BECD, as it becomes available, to aid in robust data collection and subsequent carbon benchmarking for the built environment.

Different scopes, including parts of the project/asset and/or specific life cycle stages, may be useful depending on the purpose of the assessment, for instance when comparing different solutions during early optioneering. Such smaller, localised carbon assessments are very much encouraged in order to feed into decision-making, but they do not constitute a full WLCA for the entire project.

6.1.1 Mandatory information

Asset-related technical characteristics:

1. Project name.
2. Asset type (new-build, refurbishment, fit-out, masterplan, infrastructure asset, etc.), sector and subsector (e.g. education sector – primary school).
3. UPRN (unique property reference number) if applicable.
4. Identification and description of sub-assets to include their individually compliant WLCAs.
5. Project phase (early design phase, technical design phase, etc.; or using stages in the RIBA Plan of Work if relevant).
6. Project description relevant to the stage of development, including relevant technical and functional requirements (e.g. the regulatory and client-specific requirements); pattern of use (e.g. occupancy); the shape of the buildings; and details of the construction, including the substructure, load-bearing structural frame, non-load-bearing elements, facades, roof, parking facilities, fittings and furnishings, and energy system.
7. Relationship with other WLCAs (e.g. for sub-assets if part of a multi-asset development).
8. Location (town/postcode/country).
9. Date of completion of construction (if a post-completion assessment).
10. Date of original construction if refurbishment of existing asset.
11. Anticipated start-on-site and completion dates.
12. Primary normalisation/functional unit, e.g. GIA for buildings.
13. Secondary normalisation/functional unit (typology-dependent, e.g. NIA for offices) if applicable.
14. GIA of any demolished assets.
15. Breakdown of GIA by use type (residential, retail, etc.).
16. Specifically for buildings:
    a. building height above ground and below ground (ground level taken to mean highest level at which a person can enter the building) and
    b. number of storeys above and below ground.

17 Specifically for buildings: types of main materials/technologies used in building elements (e.g. steel for vertical structure):

  a foundation

  b ground floor

  c vertical structural element

  d horizontal structural element

  e floor slab

  f cladding and

  g finishes.

18 Specifically for buildings: types of main building services (e.g. gas boiler for heating):

  a heating

  b cooling and

  c ventilation.

19 Specifically for buildings: brief description of retrofit works (if applicable) carried out for each building element:

  a substructure – foundations

  b substructure – lowest floor slab

  c superstructure – frame, upper floors, stairs and ramps

  d superstructure – roof

  e superstructure – external walls

  f superstructure – internal assemblies

  g finishes

  h fittings, furnishings and equipment

  i services (MEP) and

  j external works.

Assessment information:

1 Completed Reporting template – summary.

2 Outputs from Reporting template – buildings and Reporting template – infrastructure for the relevant project type and design stage should be included in an appendix.

3 Goal and scope of the assessment.

4 Project phase of the assessment.

5. Name/company of the assessor.
6. Date of assessment.
7. Assessment scope/type (full/shell and core/fit-out/external works, etc.).
8. Key material quantities with associated carbon factors and data sources.
9. Clear statement and explanation of key assumptions and scenarios used to facilitate the carbon calculations, such as transport distances and end-of-life scenarios.
10. Exclusions and variations from this standard.

6.1.2 Optional but recommended information

1. A conclusion recommending key emissions reduction opportunities, and the roles and responsibilities required to implement them.
2. Context type (urban/suburban/rural).
3. Scope of work carried out to retained elements, where this is relevant.
4. Alignment with other professional guidance, including IStructE, CIBSE TM65 or CWCT facade guidance.
5. Alignment with ICMS taxonomy.
6. Name/company of third-party verifier.

6.1.3 Third-party verification

Third-party verification of WLCAs against this standard – in line with the verification requirements set out in the relevant European standards (EN 15978 or EN 17472) – is recommended for WLCAs. This is to enhance quality assurance and transparency, particularly for post-completion assessments. In order to be verifiable, all information used, options or decisions taken should be presented in a transparent manner. Regulators or others who require WLCA reporting may have specific third-party verification requirements.

6.1.4 Accuracy of reporting

The carbon impacts reported must reflect the accuracy of the calculation, which will depend on the project phases at which the assessor is reporting.

- **Early design phase**: at building or asset level, calculations and totals should be reported to two significant figures (e.g. 230 kgCO_2e/m^2 or 1200 kgCO_2e/m^2 rather than 234.3 kgCO_2e/m^2 or 1234.4 kgCO_2e/m^2).
- **Technical design/construction/post-completion phase**: at building or asset level, calculations and totals should be reported to three significant figures (e.g. 234 kgCO_2e/m^2 or 1230 kgCO_2e/m^2 rather than 234.3 kgCO_2e/m^2 or 1234.4 kgCO_2e/m^2).

6.2 WLCA reporting metrics

6.2.1 Energy and carbon reporting metrics

Table 29 provides the units of measurement to be reported for the carbon boundaries identified (as described in section 2.1). Further guidance on what results must be reported, and guidance on how to structure and present them, can be found in the reporting templates.

Carbon boundary	Life cycle stages/modules	Unit of measurement
Pre-construction carbon	A0 (where relevant)	$kgCO_2e$
Upfront biogenic carbon (sequestered biogenic carbon stored in any construction products incorporated into the asset)	A1–A5	$kgCO_2e$
Upfront carbon	A0–A5, excluding sequestered biogenic carbon stored in any construction products incorporated into the asset	$kgCO_2e$
Embodied carbon	A–C, excluding B6–B8	$kgCO_2e$
Operational energy, broken down by energy type and purpose	B6	kWh/yr
Operational water usage, broken down by water type and purpose	B7	m^3/day
Operational carbon	B6 and B7	$kgCO_2e$/yr
User carbon	B8 (where relevant)	$kgCO_2e$/yr
Benefits and loads beyond system boundary	D1	$kgCO_2e$
	D2	$kgCO_2e$

Table 29: Overview of carbon reporting with the life cycle modules and units used for assessment

Notes on Table 29

- The units shown in the table are the units for asset-level assessments. The WLCA results can be reported with any clearly stated metric multiple of $kgCO_2e$, such as tonnes CO_2 equivalent (tCO_2e). Operational energy data may be provided in **megawatt hour per year** (MWh/yr), and operational water data in litres/day. **Units must always be specified.** Normalisation with metrics such as floor area or per pupil will depend on the asset.

- If module A0 (pre-construction) or either of the optional sub-modules A5.1 (pre-construction demolition) and A5.4 (transport of construction workers) have been assessed, they should be included in upfront carbon and embodied carbon, **but must also be reported separately as additional information** (for more information on A5.1 and A5.4, see section 5.1.4).
- If, at the outset of the project, there is a planned change in performance of the asset during the RSP, module B5 should be assessed in a separate WLCA, alongside a WLCA that assumes the asset remains unchanged over the RSP, where B5 will equal 0 (see section 5.2.5).

Embodied carbon includes any removals and the associated transfers or emissions of biogenic carbon at the end of life for products and components associated with reuse, recycling, other recovery or disposal of biobased materials and the use of biofuels in all modules.

6.2.2 Area measurements

This subsection specifies how to determine the floor areas of any built assets being assessed.

Floor areas from the following sources must be used and clearly stated in the WLCA, in the following order of preference and subject to availability at the different project phases:

1. 3D/BIM models and/or drawings
2. QS area schedule
3. bill of quantities (BoQ) and/or cost plan.

Information sources that are relied on for the WLCA should be cross-referenced with each other and validated as the most current versions. The floor area measurements used in a WLCA should be gross internal area (GIA), and should be reported clearly in normalised metrics, e.g. $kgCO_2e/m^2$ GIA. The exact approach to measuring GIA should also be provided in any report.

For external works, the area must be the works within the project boundary but excluding the ground-level asset footprint.

6.2.3 Normalisation units

The WLCA results for the building or asset as a whole must be reported using $kgCO_2$ equivalent ($kgCO_2e$) or any clearly stated metric multiple of it, such as tonnes CO_2 equivalent (tCO_2e).

If the project under assessment consists of one single asset, or if all sub-assets (building or infrastructure types) have a common normalisation unit, the total project-level results must also be reported against the respective normalisation unit for that asset type.

If breaking the project down into parts or sub-assets, as might be the case for larger strategic projects, agree the measuring boundaries with the wider team and align with cost reporting. **Where projects are broken down into various sub-assets (e.g. different building and/or infrastructure types), the carbon results for each sub-asset included in a project's WLCA must also be reported against the relevant normalisation units provided here, in line with their asset type, to provide an indication of their carbon intensity.**

For buildings, the normalisation units are as follows.

- **All buildings except industrial, storage and distribution**: $kgCO_2e/m^2$ gross internal area (GIA); for buildings such as sports stadiums, the area would be all normally accessible areas within the building footprint.
- **Industrial, storage and distribution**: $kgCO_2e/m^3$ of internal building volume.
- **External works**: $kgCO_2e/m^2$ of external works.

For some types of building, such as offices, net internal area (NIA) can also be used as a secondary normalisation metric, as this provides a measure of the overall efficiency of the design. This would be reported as $kgCO_2e/m^2$ NIA.

For infrastructure, the normalisation units are as follows:

Infrastructure asset type	Suggested normalisation units
Roads	km equated lane length (length of all lanes along the route, reduced to a single length) m^2 total paved area
Runways	m^2 total paved area
Bridges	m^2 total area km length
Railways	km end-to-end length (length of all tracks along the route, including those in passing loops, sidings and depots, reduced to a single length)
Tunnels	km length m^3 extracted per hour (capacity)
Wells and boreholes	m length drilled m^3 extracted over RSP or per unity capacity (e.g. m^3/hr)
Dams and reservoirs	million m^3 capacity
Waste and wastewater management and treatment works, water treatment works	megalitre output over RSP or per unity capacity (e.g. megalitre/day)
Pipelines	km length

Infrastructure asset type	Suggested normalisation units
Waterway works	km length hectare site area
Power generation plants	MW capacity MWh output over RSP
Chemical plants	tonne output over RSP or per unity capacity (e.g. tonnes output/day)
Refineries	million barrels of oil output over RSP barrels of output per day
Mines and quarries	tonne output over RSP per unity capacity (e.g. tonnes output per year) hectare site area
Offshore structures	unit output over RSP, depending on the asset (e.g. barrels crude oil, Nm^3 natural gas; for electricity see power generation)
Near-shore structures	m^2 surface area of quayside
Ports	million tonnes cargo handled over RSP 1000 passengers over RSP hectare site area
Land formation and reclamation	hectare site area
Transmission and distribution for power and data	MWh transferred over RSP per unity capacity (e.g. kV or Mbps) Megabyte transferred over RSP

Table 30: Normalisation units – infrastructure

For normalisation units based on output over the RSP, 120 years (or the RSP if this is not 120 years) must be stated. For example, this might be per MWh output over 120 years, or per barrel of oil output over an RSP of 40 years.

Additional normalisation units

Additional normalisation units, further to the recommended ones in Table 30, may be useful or required as additional carbon intensity metrics to enable fair and meaningful comparisons with similar projects, for example 'per bed' for hospitals, or 'per pupil' or 'per classroom' for schools. Appropriate additional normalisation units should be determined in line with the project brief, in agreement with the project team and/or according to any relevant industry guidance. ICMS 3 provides some relevant information for different asset types under the terms 'project quantities' and 'functional units'. The carbon results can be presented using the preferred additional normalisation units as well as the recommended ones.

6.2.4 Quantification of a built asset's physical characteristics, functional equivalents and comparisons

Where possible, if comparisons are made to other projects, they should be on the basis of their post-completion assessments.

Comparisons between the results of assessments at different project phases, on different options for projects, or for different types of project should be made on the basis of their functional equivalence for both buildings and infrastructure assets/civil engineering works.

Functional equivalence between projects/options is determined by the following key aspects:

- asset type (e.g. office building, road from points A to B)
- relevant technical and functional requirements (e.g. regulatory and client-specific requirements, capacity)
- pattern of use (e.g. occupancy) and
- required service life/design life.

The functional equivalent considers the technical and functional requirements set for the project, and forms the basis for comparisons using the basic principle that the functional equivalent is being fulfilled when those technical and functional requirements are being met or exceeded. Therefore, the concept of 'functional equivalent' is used in this context instead of 'functional unit'. The two options or versions of the project being compared do not need to have exactly the same thermal performance, m^2 of retail space, etc. Instead, they both need to meet or exceed the functional equivalent, for example the requirement set by the client that the thermal performance meets Building Regulations requirements, or that a certain area of retail space is provided.

Functional/normalisation units are provided in section 6.2.3 to aid meaningful comparisons of assessments undertaken at different phases of a project, or between assessments of different projects/options.

If assessment results based on different functional equivalents are used for comparisons, the basis for any comparison must be made clear.

The major functional requirements must be described, together with intended use and relevant specific technical requirements.

This description allows the functional equivalence of different options and different projects to be determined, and forms the basis for transparent and unbiased comparison.

6.3 Using the reporting templates

6.3.1 Reporting template contents and structure

Table 31 provides the contents, structure and purpose of each part of the reporting templates.

Table	Purpose
Reporting template – summary	
Project-level summary	Reporting of key assessment information, energy, water and grouped life cycle modules for all relevant assets/sub-assets included in the project. Reporting of both decarbonised and non-decarbonised carbon impacts, including uncertainty.
Carbon per life cycle stage non-decarbonised	Reporting of non-decarbonised carbon impacts per life cycle stage for all relevant assets/sub-assets included in the project.
Carbon per life cycle stage decarbonised	Reporting of decarbonised carbon impacts per life cycle for all relevant assets/sub-assets included in the project.
Optional reporting aligned with ICMS 3, including uncertainty	Reporting aligned with ICMS 3 (if required). Reporting of both decarbonised and non-decarbonised carbon impacts.
Reporting template – buildings	
Assessment information, energy and water	Reporting of key assessment information, energy consumption, energy generation and water for buildings and external works within the project boundary. Also, optional reporting for external works outside the project boundary.
Summary of carbon emissions by element and life cycle stage/module (non-decarbonised)	Reporting of non-decarbonised carbon impacts associated with life cycle modules for buildings and external works within and outside the project boundary.

Table	Purpose
Summary of carbon emissions by element and life cycle stage/module (decarbonised)	Reporting of decarbonised carbon impacts associated with life cycle modules for buildings and external works within and outside the project boundary.
Carbon emissions by building element and life cycle stage/ module – granularity level 1	Data breakdowns by life cycle module and building element category (see the Building element categories supporting document) for buildings at concept design stage. Data from this sheet is used to populate the 'Assessment information, energy and water' table, 'Summary of carbon emissions by element and life cycle stage/module' tables, and 'Project-level summary'.
Carbon emissions by building element and life cycle stage/ module – granularity levels 2 and 3	Data breakdowns by life cycle module and building element categories (see the Building element categories supporting document) for buildings at technical design and post-completion stages. Data from this sheet is used to the populate the 'Assessment information, energy and water' table, 'Summary of carbon emissions by element and life cycle stage/module' tables, and 'Project-level summary'.
Energy reporting, non-domestic buildings	Energy reporting for non-domestic projects. Data from this sheet is used to populate the 'Assessment information, energy and water' table, 'Summary of carbon emissions by element and life cycle stage/module' tables, and 'Project-level summary'.
Energy reporting, domestic buildings	Energy reporting for domestic projects. Data from this sheet is used to populate the 'Assessment information, energy and water' table, 'Summary of carbon emissions by element and life cycle stage/module' tables, and 'Project-level summary'.
Water reporting	Water reporting for all projects. Data from this sheet is used to populate the 'Assessment information, energy and water' table, 'Summary of carbon emissions by element and life cycle stage/module' tables, and 'Project-level summary'.

Table	Purpose
Reporting template – infrastructure	
Carbon emissions by element category and life cycle stage for infrastructure assets	Reporting per element category (see Appendix C) and by life cycle stage for infrastructure assets. Data from this sheet is used to populate 'Project-level summary', as necessary.
Energy reporting for infrastructure assets	Energy reporting for infrastructure assets.

Table 31: Using the reporting templates

Assessors are not expected to fill in detailed tables manually to produce these results. Instead, tools will transition to allow this granularity of reporting and data entry into centralised databases such as the BECD. It is expected that most users of this standard will see their results presented using the 'Assessment information, energy and water' table, 'Summary of carbon emissions by element and life cycle stage/module' tables, and 'Project-level summary' where this level of detail is required. However, the granular data breakdowns are required in a WLCA report, as they are the evidence that the full project scope has been included in the assessment.

6.3.2 Reporting template – summary

Reporting template – summary **is designed to be used for one or many sub-assets, and must be completed for every WLCA.**

When reporting a complex project with numerous different parts, such as a masterplan or infrastructure asset, each sub-asset can be listed and reported using individual normalisation units.

All reporting using this template must include the required overall WLCA uncertainty factor; see section 4.10.

The 'Project-level summary' table denotes that energy and water should be reported in their standard units to ensure completion for any scale of project, as well as consistent benchmarking across projects.

The 'Carbon per life cycle stage decarbonised' and 'Carbon per life cycle stage non-decarbonised' tables provide a format for reporting asset or sub-asset data, broken down into key life cycle modules, for decarbonised and non-decarbonised scenarios. All data in these tables is in carbon emission units and the conversions for operational emissions (energy and water) are detailed in sections 4.11.3, 5.3 and 5.4.

6.3.3 Reporting template – buildings

Reporting template – buildings is for structuring the reporting for buildings. Not all sheets will be used for each WLCA. For example, a non-domestic building at early design phase will use sheets 1, 2, 4 and 6. A domestic building at technical design phase will use sheets 1,3, 5 and 6. Data will be fed into Reporting template – summary for summary reporting.

The 'Assessment information, energy and water' table and 'Summary of carbon emissions by element and life cycle stage/module' tables are aligned with the summary reporting metrics in section 6.2.1, Table 28. **They must be used for the mandatory reporting of building(s) and associated external works within the site boundary.**

These tables also allow for optional reporting against life cycle stages A1–A5 of external works outside the project boundary.

The 'Carbon emissions by building element and life cycle stage/module – granularity level 1' and 'Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3' tables structure the input data required to generate the 'Assessment information, energy and water' table, 'Summary of carbon emissions by element and life cycle stage/module' tables and the 'Project-level summary' table in Reporting template – summary. The specific table used will depend on the design stage and granularity level of the assessment. Reporting data in the most detailed format possible is encouraged, even at an earlier design stage, as this will aid decision-making.

WLCAs must break the data down to the level of granularity used in the 'Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3' table at any phase after concept design. It is strongly recommended to use this granularity level whenever possible.

The energy and water data from the 'Energy reporting, non-domestic buildings', 'Energy reporting, domestic buildings' and 'Water reporting' tables is converted to carbon for entry into the 'Assessment information, energy and water', 'Summary of carbon emissions by element and life cycle stage/module (non-decarbonised)', 'Summary of carbon emissions by element and life cycle stage/module (decarbonised)', 'Carbon emissions by building element and life cycle stage/module – granularity level 1' and 'Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3' tables, as described in section 6.2.1, Table 29.

6.3.4 Reporting template – infrastructure

Reporting template – infrastructure provides a reporting structure for carbon impacts and energy for infrastructure assets/civil engineering works.

The 'Carbon emissions by element category and life cycle stage for infrastructure assets' table contains the breakdown of carbon impacts by element category and life cycle stage, and should be populated for all applicable elements included in the asset/sub-asset under assessment.

The 'Energy reporting for infrastructure assets' table contains information on energy consumption and generation associated with the asset/sub-asset under assessment.

Both of these should be filled out for each infrastructure asset/sub-asset included in the overall project, and will be used to populate the 'Project-level summary' table in Reporting template – summary.

6.3.5 Decarbonisation, sequestration and uncertainty

If decarbonisation is modelled, the life cycle modules that require both decarbonised and non-decarbonised figures are listed in sections 4.11.4 and 4.11.5. The reporting templates clearly denote where figures should be reported to cover each scenario.

Sequestered biogenic carbon (measured as CO_2) is deducted and reported separately for life cycle modules A1–A3 and B5. Therefore, the GWP total (the sum of GWP fossil, GWP biogenic and GWP LULUC if using EPDs and data to EN 15804+A2, or just the GWP if using EPDs and data to EN 15804+A1) should be used for all reporting, except for A1–A3 and B5. For how to calculate biogenic carbon, in order to report sequestered carbon, refer to section 4.11.1 and Appendix O.

The total GWP for each life cycle module is calculated as a subtotal. Then uncertainty is accounted for in the assessment. Uncertainty is dealt with in three parts, as shown in Figure 11 and section 4.10:

- contingency factor
- carbon data uncertainty factor and
- quantities uncertainty factor.

Each is presented as a percentage; the sum total of all three percentages provides the overall WLCA uncertainty factor.

All figures presented in the 'Project-level summary' table in Reporting template – summary must include the percentages calculated for the three different types of uncertainty and the overall WLCA uncertainty factor. The overall WLCA uncertainty factor itself, and its constituent parts, must also be reported as shown in the 'Project-level summary' table.

Figures derived from the 'Carbon per life cycle stage decarbonised' and 'Carbon per life cycle stage non-decarbonised' tables do not include any of the uncertainty factor percentages. The data in these templates is considered raw data to be transferred into the 'Project-level summary' table for the final reported results.

6.3.6 Asset-level impacts

Some impacts cannot be broken down further than an individual asset. This is relevant to the completion of the 'Carbon emissions by building element and life cycle stage/module – granularity level 1' and 'Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3' tables.

The upper rows of each sheet record impacts that cannot be broken down further than the whole entity, including any pre-construction, site or user impacts. The lower rows itemise the building element categories aligned with the Building element categories supporting document.

There are life cycle modules generated using GIA measurements, rather than quantifying building element categories. These are A5.2, B2, B3 and C1. **When reporting these life cycle modules against building element category, the assessor must pro rata the totals against the A1–A3 impacts.**

6.4 Reporting for different asset types or collections of assets

6.4.1 General approach

As previously stated, it is expected that most users will interact with this standard via an industry tool, but this is the expected order for completion of the information and the final output required. The outputs of assessments should be entered into the BECD once it becomes available.

6.4.2 Reporting for a typical new-build WLCA

The WLC assessor and the relevant design/client team parties must agree on the measuring boundaries. The carbon impacts data should also align with the cost plan for the project. This delineation will define the how the data is collected and final figures normalised.

Complete energy reporting in the 'Energy reporting, non-domestic buildings' or 'Energy reporting, domestic buildings' tables, depending on the project sector.

Complete water reporting in 'Water reporting'.

Provide material quantities and define data sources, aligned with this standard, to complete the 'Carbon emissions by building element and life cycle stage/module – granularity level 1' and 'Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3' tables, depending on the design stage of the project and the granularity level required. Decarbonised and non-decarbonised scenarios are required for the life cycle modules listed in sections 4.11.4 and 4.11.5. **Carbon conversion factors for energy and water must align with this standard.**

The above information will allow the completion of the 'Assessment information, energy and water', and 'Summary of carbon emissions by element and life cycle stage/module' (non-decarbonised and decarbonised) tables.

The 'Carbon emissions by element category and life cycle stage for infrastructure assets' and 'Energy reporting for infrastructure assets' tables should be filled out for any infrastructure asset/sub-asset that is part of the project.

The 'Project-level summary', 'Carbon per life cycle stage non-decarbonised' and 'Carbon per life cycle stage decarbonised' tables from Reporting template – summary **must be**

completed for overall project reporting. Any assets/sub-assets forming part of the project under assessment – including buildings, external works within the project boundary, infrastructure assets, etc. – must be reported as individual sub-assets. The figures can also be aggregated as required by benchmarking or project reporting.

The 'Optional reporting aligned with ICMS 3, including uncertainty' table can be used if required.

6.4.3 Reporting for a typical refurbishment WLCA

The WLC assessor and the relevant design/client team parties must agree on the measuring boundaries for new and refurbished GIA. The carbon impacts data should also align with the cost plan for the project. This delineation will define the how the data is collected and final figures normalised. See section 6.2.3.

Complete energy reporting in the 'Energy reporting, non-domestic buildings' or 'Energy reporting, domestic buildings' tables, depending on the project sector.

Complete water reporting in 'Water reporting' for the whole refurbishment asset.

Provide material quantities and define data sources, aligned with this standard, to complete the 'Carbon emissions by building element and life cycle stage/module – granularity level 1' and 'Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3' tables, depending on the design stage of the project and the granularity level required. A decarbonised and non-decarbonised scenario will be required for the life cycle modules listed in sections 4.11.4 and 4.11.5. **Carbon conversion factors for energy and water must align with this standard.**

'Carbon emissions by building element and life cycle stage/module – granularity level 1' and 'Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3' must be completed for the new GIA and refurbished GIA elements of the project.

This information will allow the completion of the 'Summary of carbon emissions by element and life cycle stage/module' tables for the new GIA and refurbished GIA. 'Assessment information, energy and water' can only be completed for the whole refurbished asset.

'Carbon emissions by element category and life cycle stage for infrastructure assets' and 'Energy reporting for infrastructure assets' should be filled out for any infrastructure asset/sub-asset that is part of the project.

The 'Project-level summary', 'Carbon per life cycle stage non-decarbonised' and 'Carbon per life cycle stage decarbonised' tables from Reporting template – summary **must be completed for overall project reporting. Any assets/sub-assets forming part of the project under assessment – including buildings, external works within the project boundary, infrastructure assets, etc. – must be reported as individual sub-assets.** The figures can also be aggregated as required by benchmarking or project reporting.

The ‘Optional reporting aligned with ICMS 3, including uncertainty’ table can be used if required.

6.4.4 Reporting for a masterplan or complex project WLCA

The WLC assessor and the relevant design/client team parties must agree on the measuring boundaries and typologies for the individual assets. The carbon impacts data should also align with the cost plan for the project. This delineation will define the how the data is collected and final figures normalised. See sections 3.5, 3.7 and 6.2.

Specific agreement should be made regarding how to distribute impacts for external works across a masterplan or collection of assets.

The whole site area at ground level, excluding the building footprints, must be reported as one total figure.

It is allowable to pro rata the allowance to each individual asset based on a normalised unit such as GIA, if required.

Complete energy reporting in ‘Energy reporting, non-domestic buildings’ or ‘Energy reporting, domestic buildings’ for each asset, depending on the asset/project sector.

Complete water reporting in ‘Water reporting’ for each asset.

Provide material quantities and define data sources, aligned with this standard, to complete the ‘Carbon emissions by building element and life cycle stage/module – granularity level 1’ and ‘Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3’ tables, depending on the design stage of the project and the granularity level required. A decarbonised and non-decarbonised scenario will be required for the life cycle modules listed in sections 4.11.4 and 4.11.5. **Carbon conversion factors for energy and water must align with this standard.**

‘Carbon emissions by building element and life cycle stage/module – granularity level 1’ and ‘Carbon emissions by building element and life cycle stage/module – granularity levels 2 and 3’ must be completed for each individual asset.

This information will allow the completion of the ‘Summary of carbon emissions by element and life cycle stage/module’ tables for each individual asset.

‘Carbon emissions by element category and life cycle stage for infrastructure assets’ and ‘Energy reporting for infrastructure assets’ should be filled out for any infrastructure asset/sub-asset that is part of the project.

The ‘Project-level summary’, ‘Carbon per life cycle stage non-decarbonised’ and ‘Carbon per life cycle stage decarbonised’ tables from Reporting template – summary must be completed for overall project reporting. Any assets/sub-assets forming part of the project under assessment – including buildings, external works within the project boundary, infrastructure assets, etc. – must be reported as individual sub-assets. The figures can also be aggregated as required by benchmarking or project reporting.

This will allow a granular understanding of the relative contribution of each to the total. The figures can be aggregated if benchmarking or project reporting requires this, as long as it is clear what is included.

The 'Optional reporting aligned with ICMS 3, including uncertainty' table can be used if required.

6.5 Communicating WLCA results to third parties

The following are mandatory requirements when communicating WLCA results to third parties if the WLCA report is not made publicly available.

Communication of WLCA results to third parties must be based on assessments in accordance with this standard and the WLCA reporting requirements in sections 6.1 and 6.2.

The mandatory information set out in section 6.1.1 must be provided in any communication (or via a link in any communication).

Module B6 must be calculated using carbon conversion factor set 2 (see section 4.9 and Appendix I).

The end-of-life scenarios modelled must be clearly stated and justified if the BAU defaults have not been used.

For assessments outside the UK, the source of any default figures used for scenarios must be stated.

Module D must always be reported alongside the other modules or life cycle stages, but separately.

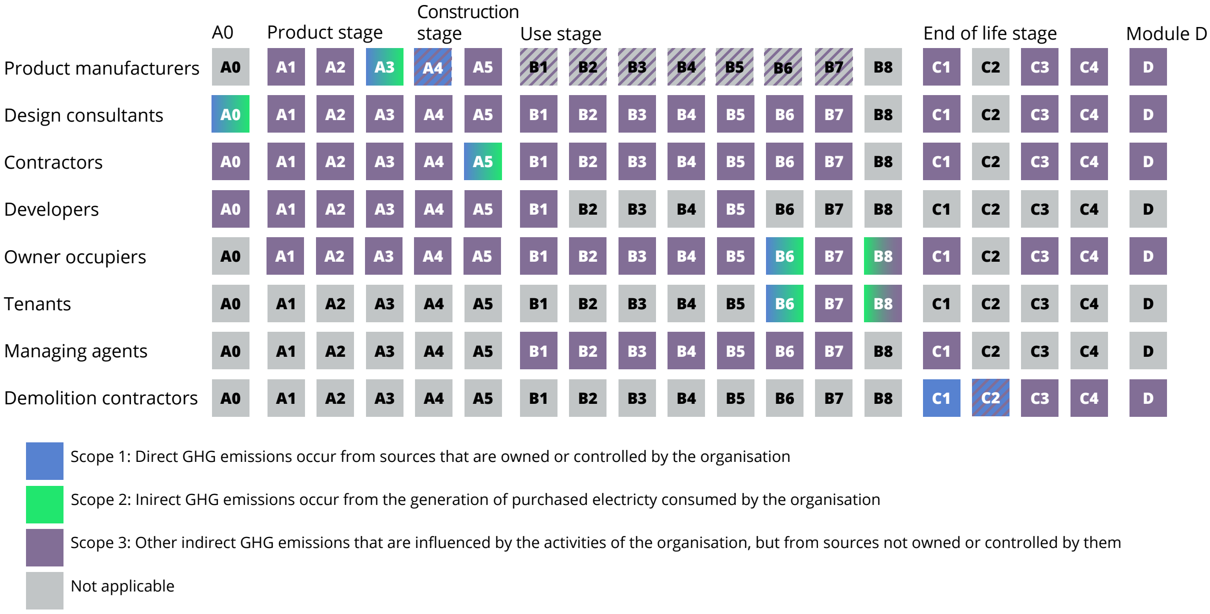
Data sources used and their quality, including the asset carbon confidence score, must be provided alongside any communication of the results.

Where decarbonisation of energy and/or materials has been applied to the results, this must be stated in any communication, and results without decarbonisation must also be reported.

Appendix A Assessment and reporting using the GHG Protocol

GRESB, CRREM and the Partnership for Carbon Accounting Financials (PCAF) have each set out their own requirements for GHG emissions reporting in the real estate sector, following the principles of the GHG Protocol. However, they only mandate the reporting of annual operational carbon emissions and do not yet provide any guidance for measuring or reporting WLC at the asset level, or embodied carbon at the organisational level, in this sector. Even where organisations include embodied carbon in their GHG reporting, there is uncertainty regarding how far the influence of an architect, for example, could be considered to extend over the life of a building they design.

This standard should be used to assess upfront and embodied carbon for constructed assets if stakeholders in the real estate and built environment sectors need to or wish to report these impacts as part of their scope 1, 2 and 3 GHG emissions. Care should be taken to consider how the assessed carbon is allocated to each scope of the GHG Protocol framework, depending on responsibility and influence. Figure A1 shows how different stakeholders may be considered to cause or influence carbon emissions or removals in the different life cycle modules, and therefore how the organisational reporting framework for the GHG Protocol might be mapped to the life cycle modules of a WLCA.



	A0	Product stage			Construction stage		Use stage								End of life stage				Module D
Product manufacturers	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Design consultants	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Contractors	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Developers	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Owner occupiers	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Tenants	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Managing agents	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Demolition contractors	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D

🟦 Scope 1: Direct GHG emissions occur from sources that are owned or controlled by the organisation

🟩 Scope 2: Inirect GHG emissions occur from the generation of purchased electricty consumed by the organisation

🟪 Scope 3: Other indirect GHG emissions that are influenced by the activities of the organisation, but from sources not owned or controlled by them

⬜ Not applicable

Figure A1: Scopes 1, 2 and 3 emissions influenced by different organisations over the asset life cycle (source: ConstructionLCA Ltd)

For example:

- GHG emissions from the manufacture of construction products in modules A1–A3 will be scope 1 and 2 emissions for manufacturers, but scope 3 emissions for both the contractor and developer using the products.
- GHG emissions from construction processes on-site in A5 will be scope 1 or 2 emissions for the contractor, but scope 3 emissions for the developer.

Different stakeholders may also apply different assessment boundaries and have different levels of control or influence depending, for example, on the type of contract or when a building is handed over to the owner. An architect may consider that through their design and specification they influence WLC throughout the building life cycle; an engineer may consider they only influence the product and construction stage carbon of the building structure. Therefore, for each stakeholder the picture may be different; Figure A1 is only an illustration of how WLC could be mapped to the reporting framework of the GHG Protocol. The UKGBC guidance on using embodied carbon assessments in scope 3 reporting provides more detail on this aspect, as does the SBTi's Buildings Sector Science Based Target Setting Guidance.

Appendix B Types and sources of embodied carbon data for materials and products

This appendix should be read in conjunction with sections 4.7 and 4.10. It describes the types of carbon data for materials and products used in a WLCA, and when they can be used. For WLCAs complying with this standard outside the UK, it provides an overview of sources of carbon data for materials that may be relevant. Finally, it explains how the carbon data confidence score can be calculated for different types of carbon data, with examples.

B1 Sources of embodied carbon data for materials and products

The BECD is intended to include carbon data for products and materials relevant to UK construction. It will be updated to list new sources of embodied carbon data as they become available, so it should be checked even if the project is not UK-based.

Outside of the UK, the following may be other useful sources of carbon data.

- Eco Platform Eco Portal: access to EPDs from Eco Platform EPD programmes around the world (provides API access).
- North American PCR Catalog: provides a list of construction product category rules (PCRs) and the relevant EPD programmes where construction product EPDs using those PCRs may be listed.
- EC3 tool: a database of construction product EPDs from around the world, although mainly from the US, with associated building impact calculator (provides API access).
- inies: a database of construction product and MEP/electrical and electronic equipment EPDs relevant to France.

Other free sources of generic data (and some EPDs) may include Circular Ecology's Inventory of Carbon and Energy (UK market-focused), the World Bank IFC EDGE program (e.g. their India Construction Materials Database), the European Commission's European Platform on LCA, ÖKOBAUDAT (German market-focused) and the Digital Environmental Hub for Global Construction Products. In addition, there are commercial LCA databases such as ecoinvent and GaBi, which provide generic data for construction materials, products and processes.

B2 Types of product- and material-level data

Table B1 provides an overview of different types of product and material carbon data with examples, and in which project phases they are most appropriately used in a WLCA.

Type of data	Example	Description	When to use?
Element benchmark data	BECD benchmark impact of external walls per m^2 GIA for hospital buildings	Average impact of a given element for a given asset type, sourced from a large number of similar assets.	Concept design: in the absence of information on the specification, this type of data can be used with the planned floor area to estimate expected impact.
Collective EPD – average product	European flexible bitumen sheet EPD Swedish sawn timber EPD	Verified data to a consistent methodology. Relevant to a specific group of manufacturers but may cover products with a wide range of impacts. Collective EPDs are also available for other regions. EPDs for large regions (like Europe) may cover a wide range of impacts.	Concept design: this is the preferred data to be used when the exact specification will not have been decided or ordered, to give the average impact of the product type. The most regionally-specific data should be used. Technical design and post-completion: this data should be used if the specific manufacturer and product specified/used are in the group but do not provide specific data. The confidence score will reflect that the manufacturer may have more impact. It can also be used as proxy data for a manufacturer not in the group or from another region (with a lower confidence score).

Type of data	Example	Description	When to use?
Collective EPD – representative product	British Precast Drainage Association – EPD for UK Manufactured DN600 Concrete Pipe with Class B Bedding – data from three member companies	Verified data to a consistent methodology. Relevant to a specific group of manufacturers and provides data for a typical or commonly used product. Other products may have a wide range of impacts. Collective EPDs are also available for other regions. EPDs for large regions (like Europe) may cover a wide range of impacts.	Concept design: this data can be used at a point when the exact specification is not decided or ordered, to give a representative impact for the product type. The most regionally-specific data should be used. Technical design and post-completion: this data should be used if the specific manufacturer and product specified/used are in the group but do not provide specific data. The confidence score will reflect that the manufacturer may have more impact. It can also be used as proxy data for a manufacturer not in the group or from another region (with a lower confidence score).

Type of data	Example	Description	When to use?
Collective EPD – specific product	Cembureau – EPD for Portland Cement (CEM I) – data provided by the national cement associations in France, Germany, Italy, Poland, Spain, UK and Turkey, covering 74% of production in Cembureau countries	Verified data to a consistent methodology. Relevant to a specific group of manufacturers and a named product. Other products may have a wide range of impacts. Collective EPDs are also available for other regions. EPDs for large regions (like Europe) may cover a wide range of impacts.	Concept design: this data can be used at a point where the exact specification is not decided or ordered, if there is no more representative data for the typical product used. The most regionally-specific data should be used. Technical design and post-completion: this data should be used if the chosen manufacturer is in the group and the product is specified. It can be used as a proxy for another product where there is no relevant EPD, but the confidence score will reflect that the actual product and/or manufacturer may have more impact. It can also be used as proxy data for a manufacturer not in the group or from another region (with a lower confidence score).

Type of data	Example	Description	When to use?
Generic LCA databases for construction	BRE IMPACT database, generic datasets from ÖKOBAUDAT, default datasets from inies, WoodforGood Database, End of life database for common framing materials	Data produced to a consistent methodology, but usually without direct data from manufacturers. May not have been peer reviewed. Will be specific to a region and may be production- or consumption-based.	Concept design: if an industry EPD is not available, this data should be used to give the average impact of the product at a point where the exact specification will not have been decided or ordered. The most regionally-specific data should be used. Technical design and post-completion: This data should be used if the manufacturer and industry EPDs are not available. It can be used as proxy data for a manufacturer from another region if the dataset is production-based. For scenario data, the description of the scenario should be checked carefully to see whether the scenario is appropriate for the project being assessed. Data could be adapted (e.g. if the transport mode is the same but the distance is different), but should not be used if the scenario is different (different transport mode, different end of life route, etc.).
Embodied carbon data/ databases	MPA Embodied Carbon data, ICE database, KBOB Oekobilanzdaten im Baubereich	Data produced to a consistent methodology, although this can vary from one database to another. It only covers embodied carbon or a very limited range of indicators, and is likely to be specific to a region. Data can be older and may not have been peer reviewed.	
Industry data	MPA Embodied Carbon data, Plastics Europe EcoProfiles, World Steel LCI database	Data may be inconsistent, using different methodologies. Data can be older and may not have been peer reviewed. For European or global data, it may cover a very wide range of impacts.	Concept design, technical design and post-completion: if no more consistent data is available, it can be used (with a lower confidence score if not verified to EN 15804).
Generic data	Values from papers, reports, etc.		

Type of data	Example	Description	When to use?
Manufacturer-specific EPD	Hanson UK Average Ready Mix Concrete EPD	Verified data to a consistent methodology. Relevant to a specific manufacturer and provides a production-weighted average for the product, but may cover products with a range of impacts.	Concept design: when this specific manufacturer's product will be used. It can be used as a proxy when no more generic data is available (with an adjustment factor). Technical design and post-completion: when this specific manufacturer's products have been specified/used and they do not have data for specific products. It can also be used as a proxy (with a lower confidence score) when another manufacturer does not provide data and there is no industry average or generic data.
Product-specific EPD	Kingspan KS1100 AB/CS Quadcore insulated panel EPD	Verified data to a consistent methodology. Relevant to a specific product from a specific manufacturer. May cover production at more than one site with different impacts.	Concept design, technical design and post-completion: when this particular product has been specified/used. It can be used as a proxy when no more generic data is available (with a lower confidence score).

Table B1: Sources of embodied carbon data for materials and processes

B3 Carbon data confidence scoring for embodied carbon data

As discussed in section 4.10, the carbon data confidence scores must be assessed using Table 13 for the ten materials datasets used in the project that have the highest impact. The intention is to consider how well the carbon dataset used matches the actual product used in the project, and therefore how confident we should be about the data.

For example, if the exact product used has a manufacturer- and site-specific EPD registered in 2022 using data collected in 2020, then using this EPD would score 40 out of 40, as it exactly represents the geography and technology used, has the exact product specificity, is an EPD with data collection from within 4 years, is the most granular type of data (site-specific data) and is an EN 15804 EPD that has been verified. This is shown as the first row in Table B2.

If a collective EPD for an average product in the EU was used for this product instead, the score would be lower. This is because the geography and technology is less representative of the actual product used (as the product is made in the UK using a specific process, and the EPD is European in scale). The product specificity is also lower, as the EPD covers a range of products, not the exact one used. In this example, the data collection period for the EPD was 2017, so the reference year/year of data collection score is lower. As the EPD is less granular (covering a wide range of sites), the granularity score is lower, but it still achieves the full points for verification as it is an EN 15804-verified EPD.

Finally, if we consider the UK product used is represented using a dataset from the ICE database based on version 2 of the database from 2011, the score would only be 13 out of 40. This is because version 2 used data that was not UK-specific or representative of UK technology, and was also not specific to the exact product used. Version 2 of the ICE database also used studies published before 2011, so the year of publication is more than 10 years ago. Finally, the dataset in version 2 is not granular, was not assessed using EN 15804 and has not been independently verified or peer reviewed.

These explanations should help in making the necessary assessments of key carbon data, which are set out in section 4.10.

Assessment in 2023 for UK-produced product	Geography	Technology	Product specificity	EPD: year of data collection	Generic data: reference year	Granularity	Verification	Total (out of 40)
Product- and manufacturer-specific EPD (2022), data collection 2020	10	6	6	8		5	5	40
Manufacturer-specific EPD (2020) for product group used, data collection in 2018	10	6	4	6		4	5	35
National average product EPD (2021), data collection 2020	10	3	4	8		3	5	33
EU average product EPD (2019), data collection 2017	4	3	4	6		3	5	25
TM65 (manufacturer data)	4	3	6		6	4	0	23

Assessment in 2023 for UK-produced product	Geography	Technology	Product specificity	EPD: year of data collection	Generic data: reference year	Granularity	Verification	Total (out of 40)
ICE database V3 2019 (only aggregates and sand, aluminium, asphalt, bitumen, bricks, cement and mortar, concrete, glass, timber and steel)	7	3-5	4		4	3	0	21-23
ecoinvent/GaBi data (2022) for similar product with similar technology for EU	4	4	4		8	3	0	23
Proxy EPD (2019) from European country, data collection 2018	4	3	2	6		0	5	20

Assessment in 2023 for UK-produced product	Geography	Technology	Product specificity	EPD: year of data collection	Generic data: reference year	Granularity	Verification	Total (out of 40)
ICE database V3 2019 (all other materials based on V2 2011)	4	3	4		0	2	0	13
TM65 (generic datapoint)	4	1	2		6	2	0	15

Table B2: Indicative data confidence scores for different types of data used to represent a specific product, produced in the UK and assessed in 2023

Appendix C Element categories for infrastructure assets/civil engineering works

This appendix identifies the element categories, based on ICMS3 groups and sub-groups, to be reported, when within the scope of the infrastructure asset(s), as applicable to the different project phases.

01	**Demolition, site preparation and formation**
01.010	Site survey and ground investigation.
01.020	Environmental treatment.
01.050	Demolition of existing structures and support to adjacent structures.
01.060	Site surface clearance (clearing, grubbing, topsoil stripping, tree felling, minor earthwork, removal).
01.080	General site formation and slope treatment (including embankments/cuttings).
01.090	Temporary surface drainage and dewatering.
01.110 (including 11.010)	Protection, diversion and relocation of – and connection to – public utilities.
01.640	Excavation (of soft silt, peat, sands, gravels, clay, rock, etc.), including mobilisation and demobilisation of excavators, blasting, transportation, disposal, reclamation, compaction and monitoring.
01.650	Dredging (of soft silt, peat, sands, gravels, clay, rock, etc.), including mobilisation and demobilisation of excavators, blasting, transportation, disposal, reclamation, compaction and monitoring.
01.660	Special disposal and treatment of contaminated sediment.

01.670	Reclamation or filling (with imported rock, concrete, or other hard materials).
02	**Substructure**
02.010	Embankments/cuttings specifically required for the project or sub-project.
02.020	Excavation, disposal and lateral supports, specifically to receive any substructure construction, but excluding general site formation and slope treatment.
02.025	Geotextile or other geomembranes.
02.030	Trenching/common trenches.
02.040	Drilling/boring.
02.050	Piling/anchoring.
02.060	Structural backfill/ground remediation.
02.070	Earth-retaining structures.
02.080	Abutments/wing walls.
02.090	Pile caps/footings/bases (nearest to the ground level or water level if constructed in water).
02.100	Sub-base for pavements and rail track structures.
02.110	Bases to supports for tanks, pipes, well heads and the like.
02.120	Beds and surrounds to underground pipes.
02.600	Pile retaining walls (combi walls/H-pile walls/secant piled walls): • sheet-piled walls • gravity quay walls • relieving platforms • pile supported structures and • special types.
02.610	Diaphragm walls.
02.620	Quays/docks/wharfs/moorings/piers/dry dock structure foundations.
02.630	Marine anchor systems.

02.640	Mooring dolphins.
02.650	Breakwaters: • cores • primary armour (interlocking units) and • secondary armour.
02.660	Rock revetments/gabions.
02.670	Cofferdams.
02.680	Bank protection.
03	**Structure**
03.010	Piers and towers.
03.020	Suspension system.
03.030	Decks.
03.040	Bearings.
03.050	Tunnel lining.
03.060 (including 11.020)	Roads/track bases, including public access roads and footpaths.
03.070	Pavements.
03.080	Service roads and approaches.
03.090	Parapets/edge treatment.
03.100	Main structures: • blindings • slabs • beams • columns and • walls.
03.105	Service stations and houses for district utility services.
03.110	Tanks, rigs, storage containers, etc.
03.120	Supports for tanks, pipes and the like.

03.130	Civil pipework.
03.140	Valves and fittings.
03.600	Seawalls.
03.610	Lake and river lining.
03.620	Prefabricated marine structures.
03.650	Slipways/gangways/linkways.
03.660	Dock and lock gates.
03.670	Pontoons.
03.680	Coastal protection systems.
03.690	Deck/surface structures (ground bearing or suspended concrete slabs).
03.700	Locks and guidance structures.
03.710	Revetments.
03.720	Flood defences.
03.730	Navigational aids.
03.740	Dry dock structures.
03.750	Weirs.
03.760	Aqueducts.
04	**Non-structural works**
04.010	Non-structural removal and alterations.
04.020	Non-structural construction.
04.030	Running surface.
04.040	Signage, markings and the like (only if permanent).
04.050	Gantries and the like (only if permanent).
05	**Services and equipment**
05.005	District heating, ventilating and cooling systems.
05.010	Mechanical systems.

05.020	Lighting systems.
05.040	Low-voltage power supply.
05.050	Cables/cable trays.
05.060	Other electrical services.
05.070	Control systems and instrumentation: • signalling systems and • telecommunications systems.
05.080	Pipe racks/supports (localised).
05.090	Water supply and drainage above ground or inside underground construction (localised).
05.100	Refuse and waste disposal systems.
05.110	Fire services.
05.115	Gas services.
05.120	Movement systems: lifts/elevators/conveyors.
05.600	Boat lifts.
05.610	Cranes/rigs/rails (only if permanent).
05.620	Underwater/sea service pipe installation.
05.630	Underwater/sea electrical/data cabling.
06	**Surface and underground drainage**
06.010	Surface water drainage.
06.020	Storm water drainage.
06.030	Foul and wastewater drainage.
06.040	Pumping systems.
07	**External and ancillary works**
07.010	Site enclosures and divisions.
07.020	Ancillary structures.
07.030	Roads and paving (not qualifying as a standalone road project).

07.040	Landscaping (hard and soft).
08	**Preliminaries/constructors’ site overheads/general requirements**
08.020 (including 01.100)	Temporary access roads and storage areas, traffic management and diversion.
08.025	Temporary concrete batching yard, precast concrete casting yard.
08.030 (including 01.040)	Temporary site fencing and securities.
08.045	Marine plant and equipment, e.g. ships/barges/vessels, floating cranes, dredgers, floating drill rigs, cofferdams, caissons (only if permanent).
08.055	Worker living accommodation.
08.060	Other temporary facilities and services.
12	**Production and loose furniture, fittings and equipment (including related risk allowances, taxes and levies)**
12.020	Fixed production, process and operating furniture, fittings and equipment installed before completion of construction.

Appendix D Types of infrastructure assets/civil engineering works

Bridges	Structures designed to span across a physical obstacle, including viaducts and culverts.
Chemical plants	Facilities for the creation of chemical products, excluding petrochemicals but including relevant tanks.
Dams and reservoirs	Artificial barriers to stop and/or restrict the flow of water, including underground streams. Reservoirs created by dams may provide water for irrigation, human consumption, industrial use, recreation, aquaculture and navigation.
Land formation and reclamation	Pieces of land formed/landscaped or reclaimed to provide land for future development or self-completed as parks, open plazas, parking lots, airfields, recreation areas, sports grounds, etc.
Mines and quarries	Sites where extraction of minerals and/or other geological materials is taking place by mining, quarrying or pumping, including relevant processing operations that use heat and/or chemical treatment to separate the metal or other substance of interest.
Nearshore works	Engineered/designed structures and facilities located nearshore for the purposes of land reclamation and coastal protection, excluding dams but including flood barriers.
Offshore structures	Engineered/designed structures and facilities, mainly constructed and pre-commissioned onshore, installed offshore in either fresh or sea water for the purpose of extraction, production or transmission of electricity, oil, gas or other natural resources, including offshore mining. Also includes rigs and platforms, dredging, jetties, etc.
Pipelines	Series of pipes and tubing for the transfer of liquid, gas or powder.
Ports	Engineered/designed structures and facilities to provide mooring for water transport, including docks.

Power-generation plants	Facilities for the generation of electrical power, including fossil- and nuclear-powered plants, and renewable energy facilities.
Railways	Permanent ways comprising a rail track composed of two parallel rails fixed to sleepers or a single monorail (includes spurs, sidings and turnouts for train traffic or the like), including tramways, metro rails, light rails, other rapid mass transit systems and cable cars.
Refineries	Processing facilities for the production of petrochemical products, including relevant tanks.
Roads and runways	Pavements providing a thoroughfare, route or way for vehicular traffic on land between two or more places, including but not limited to alleys, streets, collector and rural roads, motorways, expressways, county and interstate highways, hardstandings, cycle paths and footpaths.
Tunnels	Artificial enclosed underground or underwater passageways, commonly with main access for entrance and exit at each end, and openings for ventilation and emergency or maintenance access. These include bored, mined, drill and blast, and cut and cover.
Waste and wastewater management and treatment works	Facilities for waste processing and for the cleaning and improvement of wastewater that contains waste products, contaminants or pollutants in order to make the outputs safe for discharge. These include drainage, sewage and relevant tanks.
Water treatment works	Facilities for the cleaning and improvement of water to make it potable, including relevant tanks.
Waterway works	Engineered/designed structures and facilities to alter/protect natural waterways and provide artificial waterways for water transport. Includes canals, locks, channels, basins, dykes, aqueducts, etc.
Wells and boreholes	Facilities, including relevant tanks, for drilling or boring into the ground for extraction of a natural resource or the injection of a fluid, or for the evaluation/monitoring of subsurface formations.

Table D1: ICMS 3 classification of infrastructure assets/civil engineering works

Appendix E Guidance for measuring building elements (normative)

This appendix provides colour-coded diagrams that define where specific parts of buildings are reported. The content relates to section 3.2 and Appendix C. **The distributions are mandatory to ensure consistency of measurement and reporting.** These diagrams show how to allocate different parts of the building consistently where there is the potential for confusion to arise. The embodied emissions from each building element are then combined into the reporting format in Reporting template – buildings.

The numbering of elements is referenced in Appendix C.

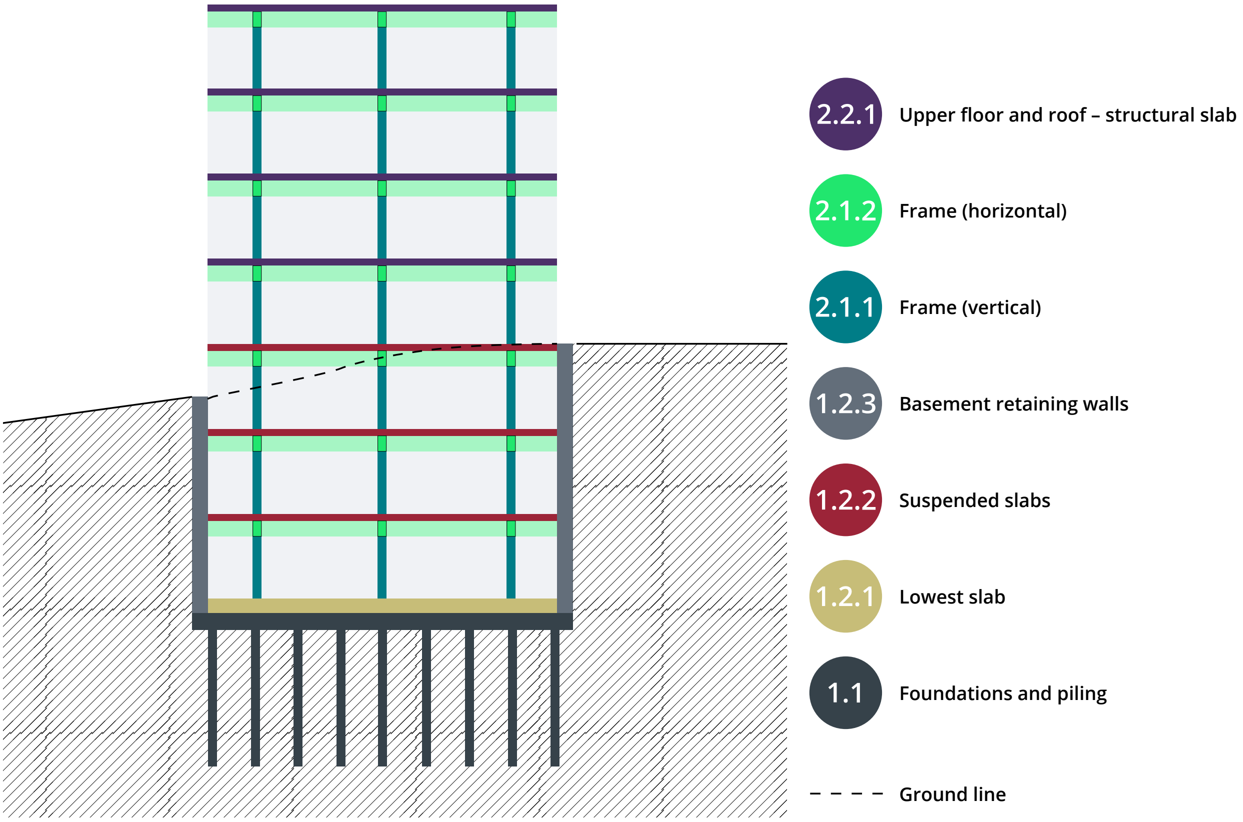


Figure E1: Typical multistorey structural strategy, including basement and sloping ground (indicated by dotted line), showing designation of structural building elements

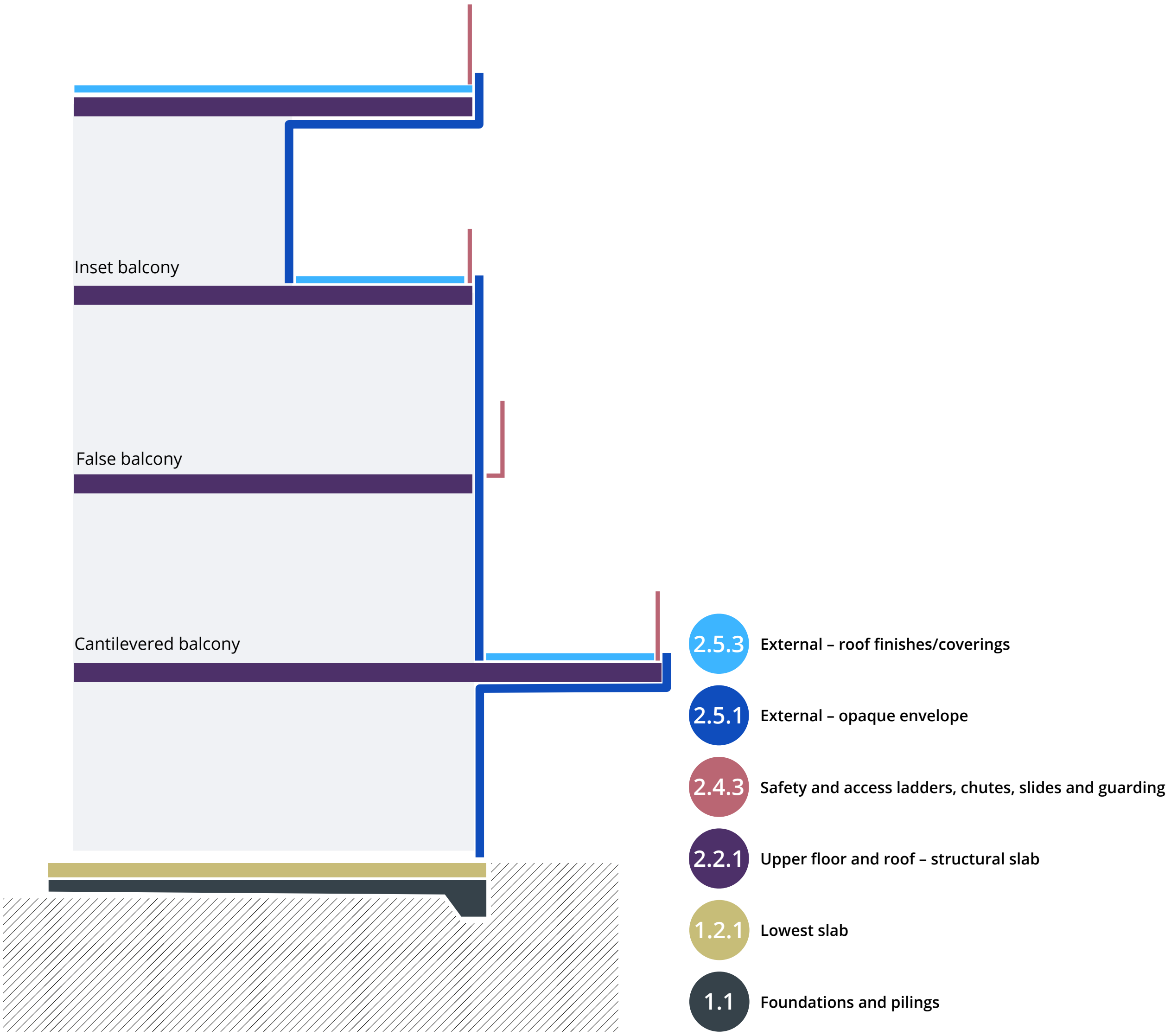


Figure E2: Typical multistorey structural and envelope strategy with inset and bolt-on balconies

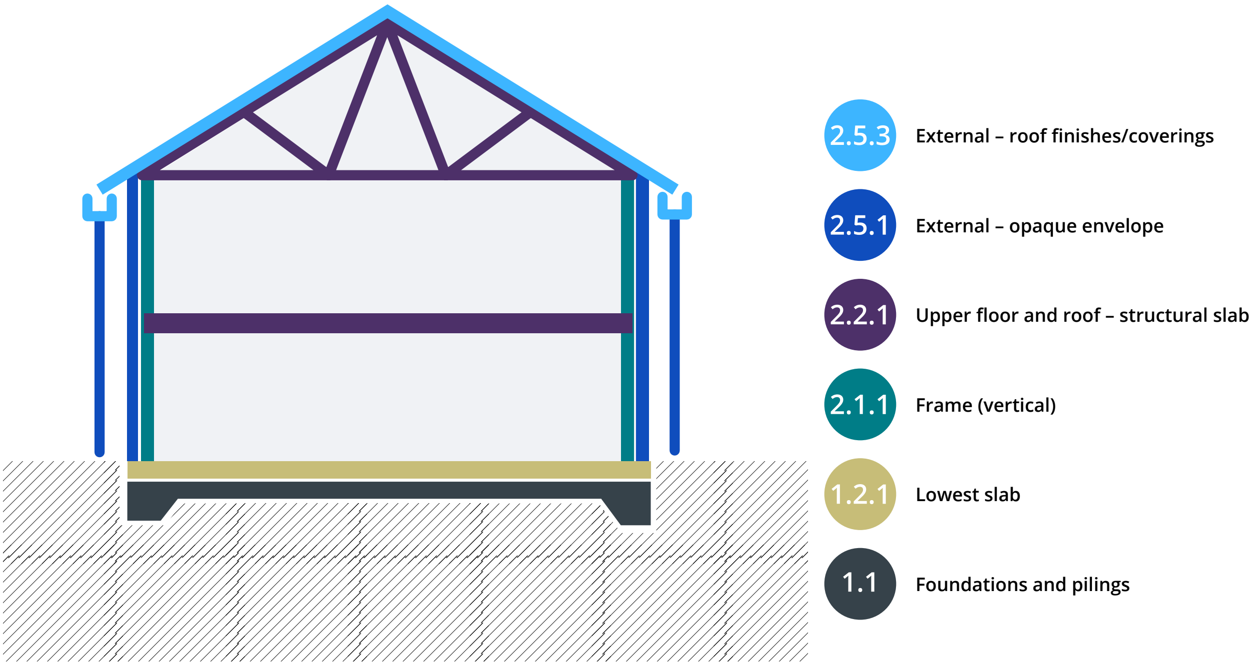


Figure E3: Typical domestic or low-rise building asset, showing designation of structural and external envelope building elements

Figure E4 should be read in conjunction with section 3.5 and confirms the allocation of structural and architectural elements in Reporting template – buildings.

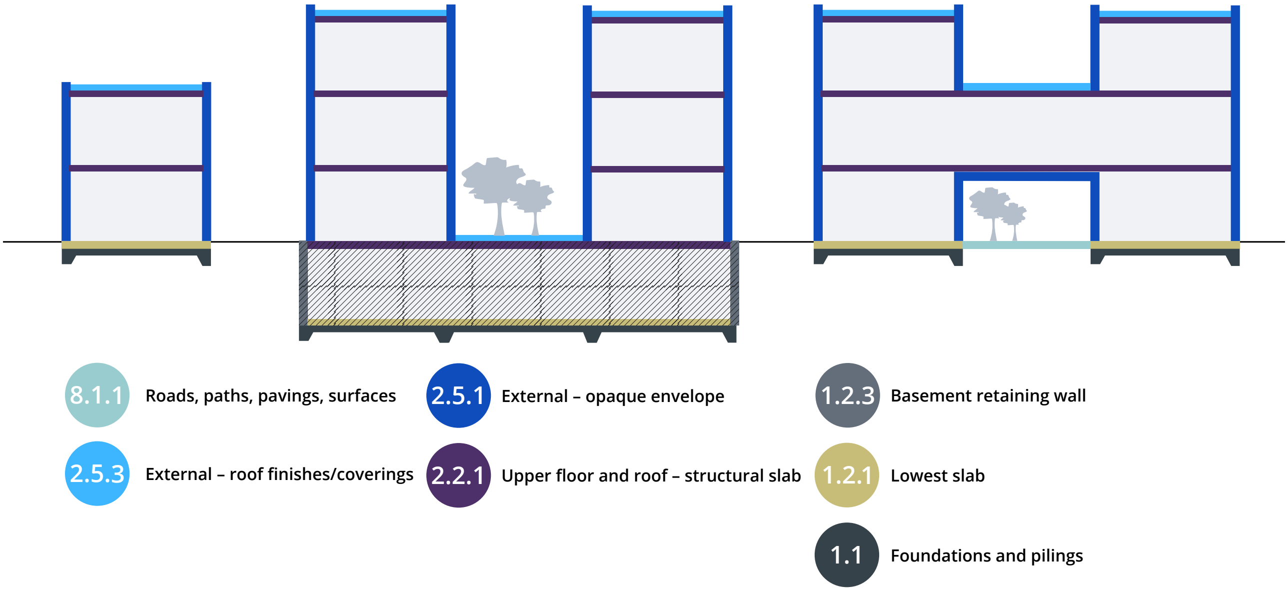


Figure E4: Example of how external envelope and roof finishes should be measured across different building types

E1 MEP distribution between building and external works

This series of figures shows how to allocate the parts of specific MEP strategies in Appendix C and the reporting templates.

E1.1 Electricity and power

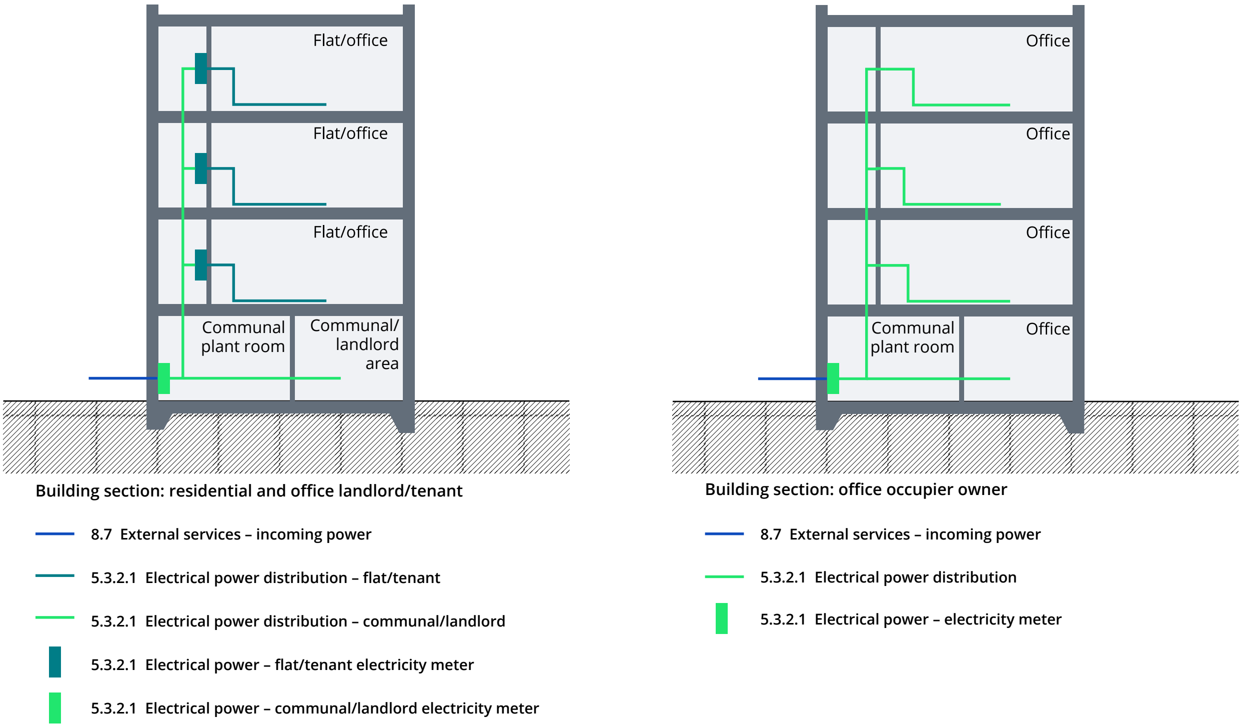
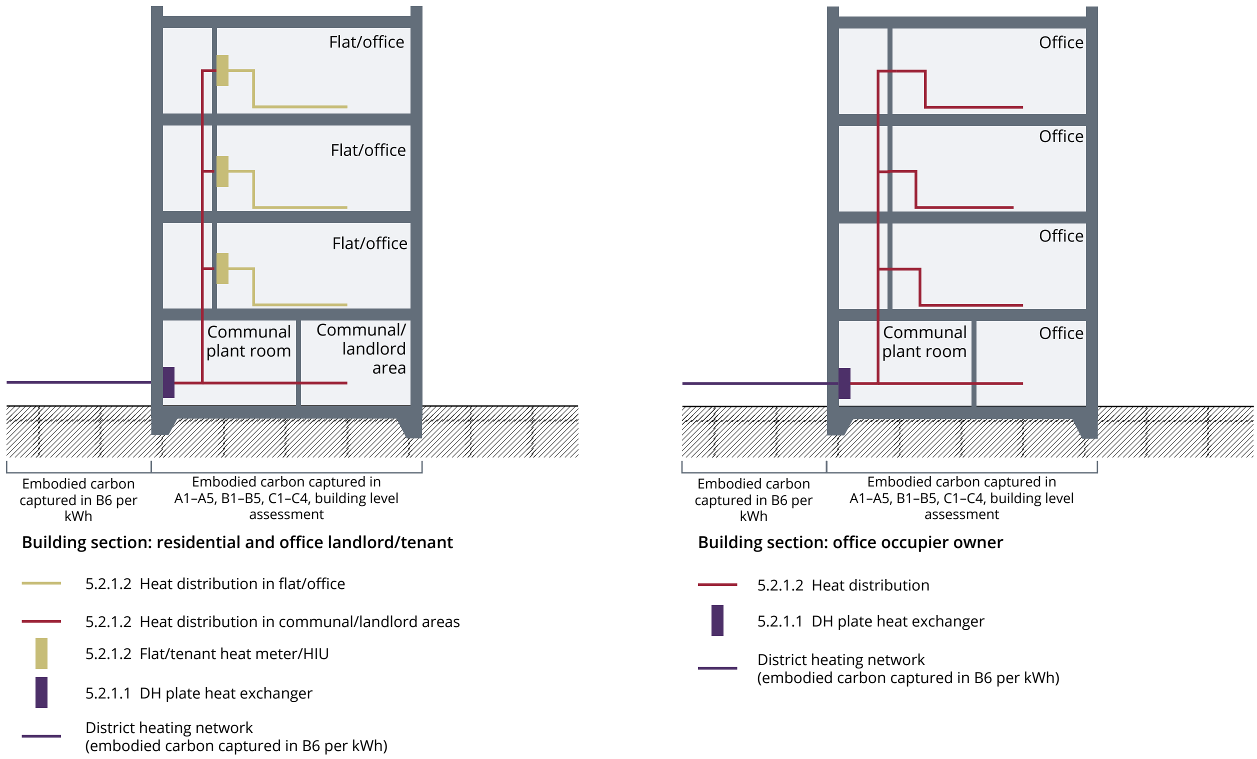


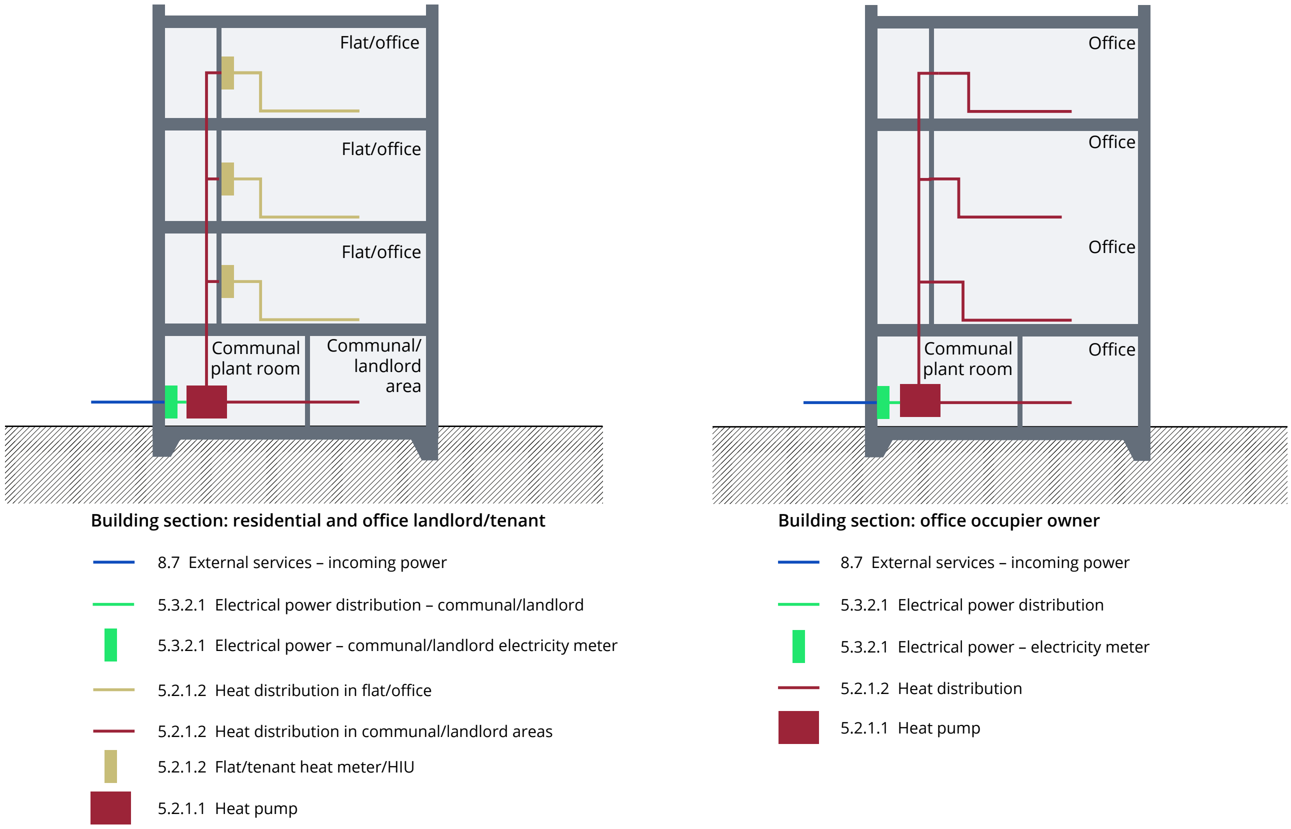
Figure E5: MEP distribution between building and external works for electrical power; also denotes landlord/tenant separation, where relevant



Building section: residential and office landlord/tenant

Building section: office occupier owner

Figure E6: MEP distribution between building and external works for communal heating systems; also denotes landlord/tenant separation, where relevant



Building section: residential and office landlord/tenant

Building section: office occupier owner

Figure E7: MEP distribution between building and external works for district heating systems; also denotes landlord/tenant separation, where relevant

Appendix F MEP

This appendix is supported by the MEP – supplementary tables supporting document, which has been provided as a separate download.

The challenges around estimating the embodied carbon of MEP designs are due to:

- the lack of embodied carbon data at the product level and
- the lack of information concerning quantities.

F1 MEP and embodied carbon data

To address the current lack of EPDs for MEP products, CIBSE published TM65 – Embodied carbon of building services: A calculation methodology. TM65 provides an international methodology for estimating the embodied carbon of MEP products when no EPDs are available. The methodology sets out two alternative calculation methods, depending on the amount of information available from manufacturers: a basic and a mid-level calculation method. The mid-level is more robust and should be the preferred choice.

The TM65 methodology covers only embodied carbon at the product level; the rest of the life cycle stages should be calculated following the methodology in this standard. Local addenda are being created in different international regions in order to pair global consistency with local relevance, and should be used where available. CIBSE is working on a product-level MEP embodied carbon database to provide useful data and enable calculations at the early design stage, similarly to generic EPDs. **However, if EPDs for MEP products are available, these must be favoured over TM65 datapoints.**

F2 MEP and quantities measurement

To address the current lack of information concerning quantities, Appendix F2 provides guidance to help cover quantity measurement throughout the design.

F2.1 At the early design phase

If no information regarding MEP quantities is available from the quantity surveyor or the MEP engineers at the concept design phase, the MEP – supplementary tables document can be used for embodied carbon assessments for commercial shell and core, commercial Cat A and residential buildings. It lists average take-off assumptions, based on the information an MEP engineer should be able to provide at the early design phase.

BIM can also be used to generate both area- and function-based assessments during early project phases where building programming and area-based embodied carbon factors are available.

F2.2 At the technical design phase

During later project phases, BIM quantity take-offs provide more detailed evaluations. However, it is critical to understand what is and is not represented in the building model, so that elements that are not represented can be accounted for. A review of a project's or model's execution plans will provide guidance as to what is or is not fully modelled.

Fully detailed as-built or fabrication models will lead to the most accurate quantity take-offs; however, assessors should review project documentation to identify and compensate for elements that were installed but not modelled. Elements that are often not modelled include supports, small-sized piping and conduits, electrical wiring and cabling, miscellaneous isolation valves and piping accessories such as drain points and seismic restraints.

F2.3 At all design phases: simplification of MEP take-off

Some MEP elements are rarely modelled but can be estimated quite easily throughout the design phases, such as pipe and duct support, insulation and fittings. The following are examples of typical assumptions that can be made if no other information is available.

- Pipe and duct support (typically measured in kg): different types of support exist: wires, hangers and supports. Based on the total length of pipe/duct, it is possible to work out a total weight of support (typically stainless steel) with the following assumptions:
  - two hangers every 3m, each 0.5m long and 0.01m in diameter, and
  - one unistrut every 3m, 0.5m long, 0.05m wide and 0.005m thick.
- Pipe and duct insulation (typically measured in m^3): if the length and sizes of pipe or duct are known, and the thickness of insulation, then the external diameter of the pipework is also known and it is possible to work out the total volume of insulation in m^3.
- 90° bend elbow pipe: if the number of bends is known, assume 0.1m of equivalent length of pipe per fitting and then work out, based on the materiality (with the density), the total volume and mass.
- T pipe: this is the same method as for elbow pipe, but assume 0.15m of equivalent length of pipe per fitting.

In terms of typical material breakdown, if no information is given by the engineers for the project, the following can be assumed for the different types of pipework:

- cast iron for drainage
- copper for domestic water, chilled water, heating water
- PEX for domestic water, chilled water, heating water
- galvanised steel for chilled water, heating water, domestic water, sprinklers.

F3 What to do when there is no data

If no information on the embodied carbon of the specific MEP product is available, the mass of the equipment should be used instead. The mass should be then multiplied by a $kgCO_2e/kg$ value. This value should come from the closest EPD or TM65 match for a similar product of another size or capacity. If no EPD or TM65 data is available for this category of products, an average MEP $kgCO_2e/kg$ of the current data available (using CIBSE resources and its upcoming database for instance) should be used. The replacement rates according to the study period should be then factored into the overall building WLC calculations.

An overall percentage of the total building's embodied carbon impact should not be used, as the embodied carbon impact of MEP varies greatly according to the design strategy in place. Refer to CIBSE TM65 publications for more information.

Appendix G Operational energy decarbonisation

G1 Decarbonisation scenarios for operational energy

Electricity can be produced in many different ways, and the electricity grid usually contains a mix. The carbon impact associated with electricity use within a built asset therefore depends on this mix. In most countries, the carbon impacts of electricity have reduced over the last 10 years, and it is predicted that they will reduce further in the future; this process is called decarbonisation.

Decarbonisation applies to carbon impacts associated with electricity use, production, distribution and storage (see Appendix H for more information on the energy supply chain).

When estimating the operational carbon impacts associated with energy consumption of a built asset (B6), carbon factors (kgCO_2e/kWh) per type of energy are multiplied according to the energy consumption (kWh). **Along with other scenarios that must be calculated, a decarbonisation scenario must be calculated.** This decarbonisation scenario requires the use of a decarbonisation carbon factor. This appendix provides guidance on how to calculate this decarbonisation carbon factor.

As a general rule, decarbonisation carbon factor projections published by central governments or designated bodies should be used. If there is a range of scenarios, the most conservative scenario should be used.

When carrying out WLC calculations over the RSP, the average carbon factor over the RSP must be used.

G2 Decarbonisation scenarios in the UK

In the UK, the falling short scenario (excluding negative emissions from BECCS), from the latest Future Energy Scenarios (FES) developed by National Grid, must be used for the decarbonisation scenario. FES currently provide carbon factors only until 2050; if the RSP runs beyond that year, it should be assumed that carbon emissions remain stable after this point, with an average created for the whole RSP (see Figure G1).

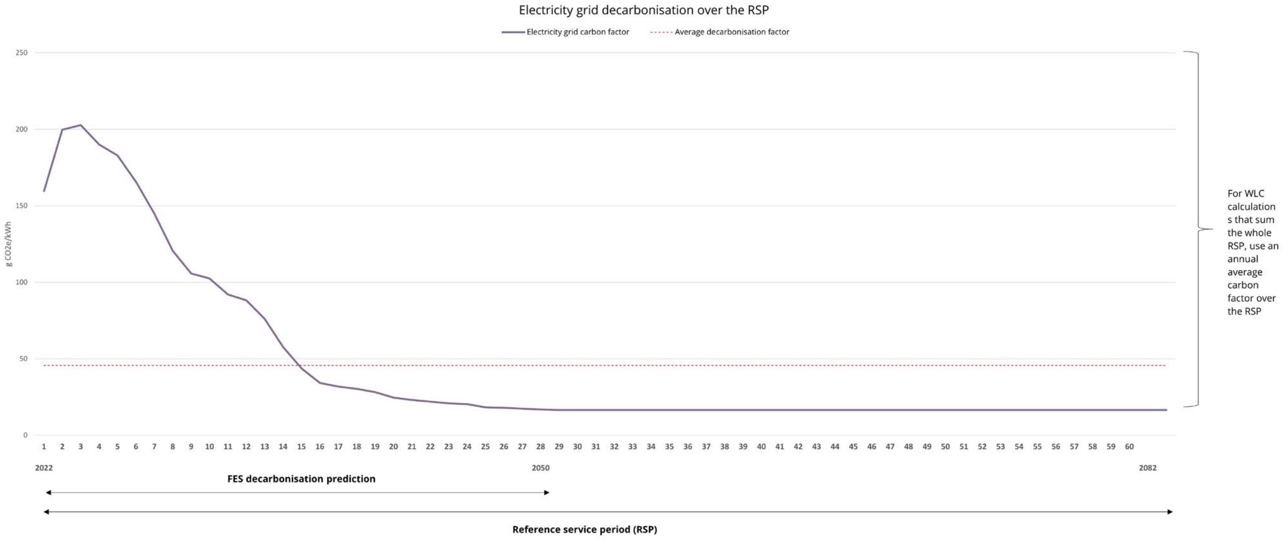


Figure G1: UK grid decarbonisation over the next 60 years in the UK using the FES 2022 decarbonisation falling short scenario (source: Introba)

G3 What to do when decarbonisation scenarios do not exist

Where possible, scenarios produced by national governments and designated bodies should be used for different countries. Where decarbonisation scenarios do not exist in the country of the assessment, the assessor should look for other data, for example CRREM decarbonisation trajectories. Priority should be given to internationally recognised organisations, and national or regional government agencies, considering the quality of data and methodologies employed. Additionally, the update frequency and timeliness of sources should be taken into account to help maintain the accuracy and relevance of the projections.

Where data does not exist, the assessor should choose the trajectory of a country that has a similar carbon factor for the previous year. **It must be stated clearly in the WLCA what assumptions have been taken and why.**

G4 Decarbonisation of upstream emissions

Under the decarbonisation scenario, the upstream emissions associated with energy production, distribution and storage that require electricity must also decarbonised. If data for this is not available, an energy decarbonisation factor should be applied to these emissions to produce a decarbonised value.

The energy decarbonisation factor must be calculated by dividing the average decarbonisation factor over the RSP for the direct emissions by the current direct emissions carbon factor for electricity:

> **Energy decarbonisation factor = decarbonised carbon factor over a RSP of 60 years for direct emissions / current carbon factor for direct emissions**

As an example, using 2023 data for the UK produces the following result (figures used here are the latest at the time of publication; up-to-date figures should be used wherever possible):

1. Average decarbonisation factor for FES falling short scenario: 0.0413 kgCO_2e/kWh
2. 2023 electricity carbon factor from UK Government GHG Conversion Factors (excluding T&D and WTT): 0.2071 kgCO_2e/kWh
3. Energy decarbonisation factor = 0.0413/0.2071= 0.2 over 60 years

This energy decarbonisation factor must be applied to all relevant upstream emissions and B7 emissions. Here is a UK example:

Decarbonised WTT = non decarbonised WTT x energy decarbonisation factor x RSP

Decarbonised WTT = 0.0459 x 0.2 = 0.00918 kgCO_2e/kWh x RSP

An embodied carbon decarbonisation factor must also be applied to the embodied carbon of energy infrastructure; the same assumptions are used as in section 4.11.5 (i.e. a factor of 0.5).

See the ‘Carbon conversion sets – generic’ tab in the Energy – supplementary tables document for more details.

Appendix H Energy supply chain carbon accounting for module B6

This appendix outlines the different carbon emissions associated with energy use within a built asset that should be accounted for in a built asset WLCA.

H1 Emissions associated with energy usage

Energy usage in buildings is responsible for different types of carbon emissions:

- direct emissions associated with energy generation (scope 2), distribution (T&D/scope 3) and use (scope 1, e.g. combustion)
- indirect emissions associated with energy generation and distribution (WTT/scope 3), and
- indirect emissions associated with the embodied carbon of the infrastructure needed to generate, distribute and store the energy (scope 3).

It is important to understand the whole energy supply chain when choosing a carbon conversion factor for B6 calculations. **For a WLCA over the RSP, carbon conversion factors must include all emissions listed above.**

Table H1 details the types of carbon emissions that occur through energy generation, distribution, storage and use in the building per type of energy source.

	Energy generation			Energy distribution and storage			Energy use in the building
Energy supply chain	Upstream emissions						Operational emissions
	Indirect emissions from the production of infrastructure to extract/create/process the energy.	Indirect emissions from fuel extraction, distribution to generator site and processing.	Direct emissions from energy generation offsite.	Indirect emissions from production of the energy distribution infrastructure and storage.	Indirect emissions from energy consumption to store and distribute the energy to the building.	Direct emissions from energy distribution and storage.	Direct emissions from burning fuels onsite.
	Upstream emissions – embodied	Upstream emissions – operational (WTT)	Operational emissions	Upstream emissions – embodied	Upstream emissions – operational (WTT)	Upstream emissions – operational (T&D)	Operational emissions
	Scope 3	Scope 3	Scope 2	Scope 3	Scope 3	Scope 3	Scope 1

By energy type	Upstream processes			Distribution and storage			Use in the building
Electricity grid	Build, maintain and end of life of the infrastructure of the plant where the electricity is created, and the infrastructure needed to extract and distribute any fuel to create the electricity.	Energy associated with extracting and distributing any fuels needed to generate electricity. Not applicable if from renewables, except biomass; see below.	Burning gas and other fuels to create electricity.	Build, maintain and end of life of the network for distribution (pylons, wire, transformers, etc.) and storage facility (dam, etc.).	Energy associated with extracting and distributing any fuels required to produce the energy lost, or used in distribution and storage of energy from the grid.	Losses during distribution and storage, and SF6 leakage in switchgears.	
Onsite renewables used onsite	Build, maintain and end of life of onsite renewable installations.						

By energy type	Upstream processes			Distribution and storage			Use in the building
Onsite renewables exported to the grid and used again by the building in the same year (match annual consumption)	Build, maintain and end of life of onsite renewable installations.			Build, maintain and end of life of the network for distribution (pylons, wire, transformers, etc.) and storage facility (dam, etc.).	Energy associated with extracting and distributing any fuels required to produce the energy lost, or used in distribution and storage of energy to and from the grid.	Losses during distribution and storage, and SF6 leakage in switchgears.	
Onsite renewables for export only	Build, maintain and end of life of onsite renewable installations, but accounted for by the building that uses it.			Build, maintain and end of life of the network for distribution (pylons, wire, transformers, etc.) and storage facility (dam, etc.).	Energy associated with extracting and distributing any fuels required to produce the energy lost, or used in distribution and storage of energy to the grid.	Losses during distribution and storage, and SF6 leakage in switchgears.	

By energy type	Upstream processes			Distribution and storage			Use in the building
Gas (natural gas and biogas)	Build, maintain and end of life of: • plant to extract the natural gas offshore or on land, and • processing plant for clean raw natural gas.	Energy associated with extraction and distribution of the natural gas to the processing plant.		Build, maintain and end of life of the pipelines to distribute the gas and infrastructure needed for storage.	Energy associated with extracting and distributing any fuels required to produce the energy used in distribution and storage of gas.	Gas leaks in pipes, and energy required to distribute and store the gas.	Burning natural gas.

By energy type	Upstream processes			Distribution and storage			Use in the building
Biomass	Build, maintain and end of life of the sawmill, forest roads, pellet factory, etc.	Energy associated with growing (includes making the fertilizers), harvesting and processing the biomass (e.g. pellet processing).		Build, maintain and end of life of the infrastructure storage.	Energy required to distribute and store the biomass.		Burning biomass and disposal of the ashes.
District heating	Build, maintain and end of life of the DHN plant.	Energy associated with extracting and distributing the fuels to the generator site.	Burning gas and other fuels.	Build, maintain and end of life of the pipeline network for distribution.	Energy associated with extracting and distributing any fuels required to produce the energy used in distribution and storage of gas.	Losses in pipes and power needed to distribute.	

Table H1: Energy infrastructure carbon emissions breakdown (source: Introba)

H2 Life cycle modules

The carbon emissions associated with the energy supply chain should be accounted in the different life cycle stages, as shown in Table H2. Where energy is generated onsite, the embodied carbon impact should be accounted for in A1–A5, B1–B4 and C1–C4; where energy is generated offsite, it is included in B6.

H3 Embodied carbon of energy infrastructure

The embodied carbon of energy infrastructure should be included in building-level embodied carbon calculations, as the more energy that built assets use, the larger the energy grid infrastructure needs to be.

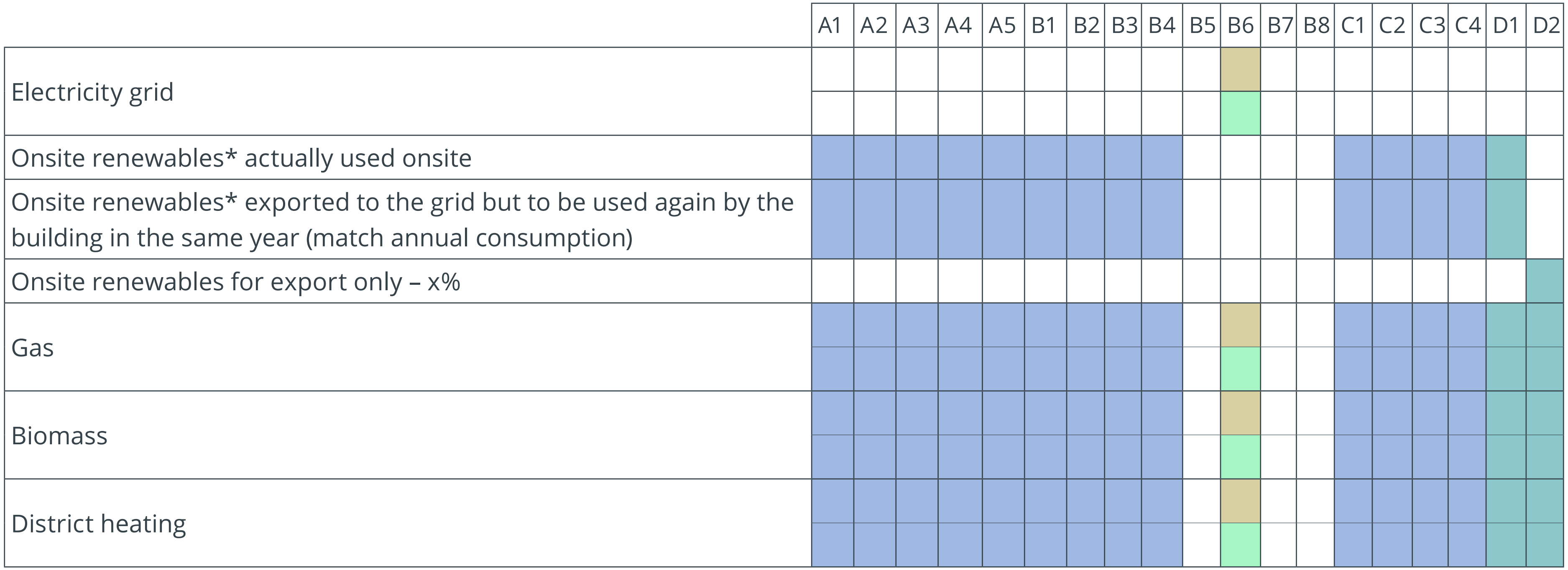
As highlighted in Table H1, the embodied carbon of energy infrastructure can be divided into the following:

- **Upstream embodied carbon used to generate the energy:** this is the embodied carbon required to build, maintain and end of life the infrastructure of the plant where the energy is created – as well as the infrastructure needed to extract and distribute the fuel to create the energy in the case of electricity.
- **Upstream embodied carbon from energy distribution infrastructure and storage:** this includes the embodied carbon to build, maintain and end of life the distribution network (pylons, wire, transformers, etc.) and storage facility (dams, etc.).

Not all available energy carbon factor sources include the embodied carbon of the infrastructure in their values. For instance, ecoinvent and GaBi do include some embodied carbon emissions of infrastructure for renewables, whereas the UK Government conversion factors for company reporting of greenhouse gas emissions do not.

he building site should be included as part of B6, and is accounted for as a factor that is applied to the kWh/yr of delivered energy.

As highlighted in Table H2, the embodied carbon of energy infrastructure that is outside of the building site should be included as part of B6, and is accounted for as a factor that is applied to the kWh/yr of delivered energy.



	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D1	D2
Electricity grid											🟫								
											🟩								
Onsite renewables* actually used onsite	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					🟦	🟦	🟦	🟦	▨	
Onsite renewables* exported to the grid but to be used again by the building in the same year (match annual consumption)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					🟦	🟦	🟦	🟦	▨	
Onsite renewables for export only – x%																			▨
Gas	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟫			🟦	🟦	🟦	🟦	▨	▨
	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟩			🟦	🟦	🟦	🟦	▨	▨
Biomass	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟫			🟦	🟦	🟦	🟦	▨	▨
	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟩			🟦	🟦	🟦	🟦	▨	▨
District heating	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟫			🟦	🟦	🟦	🟦	▨	▨
	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		🟩			🟦	🟦	🟦	🟦	▨	▨

Key	
Embodied carbon	🟦 A, B, C
	🟩 in B6
Operational energy	🟫 in B6
Beyond the life cycle	▨ D1
	▨ D2

	Embodied carbon		Operational energy	Beyond the life cycle	
	A, B, C	in B6	in B6	D1	D2
Electricity grid	n/a	Embodied carbon of the infrastructure to generate, distribute and store the electricity	Direct and indirect emissions	n/a	n/a
Onsite renewables – that which is actually used onsite	Embodied carbon of the onsite renewables	n/a	0	If the onsite renewables get recycled or recovered	n/a
Onsite renewables – that which are exported to the grid but to be used again by the building in the same year (match annual consumption)	Embodied carbon of the onsite renewables	Embodied carbon of the infrastructure to distribute and store the electricity, and embodied carbon of the infrastructure to generate the electricity to cover the losses	Direct and indirect emissions	If the onsite renewables get recycled or recovered	n/a
Onsite renewables – net annual export only	n/a	n/a	n/a	n/a	Energy exported
Gas	Embodied carbon of the gas equipment in the building and the heating system	Embodied carbon of the infrastructure to generate, distribute and store the gas, which is considered minimal and therefore not included in calculations	Direct and indirect emissions	If the combustion equipment gets recycled or recovered	n/a
Biomass	Embodied carbon of the biomass equipment and the heating system in the building, and disposal of the ashes	Embodied carbon of the infrastructure to generate, distribute and store the biomass, which is considered minimal so not included in calculations	Direct and indirect emissions	If the biomass equipment gets recycled or recovered	n/a
District heating	Embodied carbon of the heating system up to the plate heat exchanger	Embodied carbon of the district plant	Direct and indirect emissions	If the onsite equipment gets recycled or recovered	n/a

Table H2: Life cycle modules for energy infrastructure carbon emissions accounting (source: Introba)

H4 Treatment of renewables

H4.1 Carbon accounting for renewables

Offsite renewables

For the purposes of carbon accounting in WLCAs, the following offsite renewables are assumed to be the same as the grid average:

- renewable energy production with a direct feed to the asset
- an investment into additional renewable energy capacity offsite
- a renewable energy power purchase agreement for a minimum period, e.g. 15 years, or
- a green tariff.

Onsite renewables

Depending on the purpose of the assessment, the carbon benefit of onsite renewables is included or not included in the WLCA, as shown in Table H3.

Purpose of the assessment	Carbon conversion factor set	Years in the assessment	Decarbonisation scenario	Treatment of onsite renewables
To understand the WLC consequences of design decisions (e.g. additional insulation or heating system type)	Set 1	RSP, e.g. 60 years	a Non-decarbonised scenario b Decarbonised scenario c Net-zero-grid-compatible scenario	Onsite renewables: not included. Reasoning: whether the building does or does not have onsite renewables should not impact building-level trade-offs between operational and embodied carbon.
To be able to benchmark the WLC of a project against other projects or industry benchmarks, and predict the carbon emissions over the RSP, e.g. to predict carbon offsetting.	Set 2	RSP, e.g. 60 years	a Non-decarbonised scenario b Decarbonised scenario	Onsite renewables: included. Reasoning: the benefit of onsite renewables should be included in order to compare projects.
For annual reporting purposes, to calculate the carbon associated with B6 for a given year, e.g. to pay annual carbon offsetting.	Set 3	1 year	n/a – annual assessment	Onsite renewables: Included Reasoning: the benefit of onsite renewables should be included in order to accurately report carbon emissions.

Table H3: Treatment of onsite renewables

H4.2 Renewable energy generation categorisation

For the majority of assets that have significant renewable energy production, a significant amount of electricity is exported to the electricity grid, as there is likely to be a mismatch between instantaneous demand and energy production.

There are three categories of onsite renewable energy generation, accounted for in A1–A5, B1–B4 and C1–C5, as shown in Table H4.

Category of onsite renewable energy generation	Operational carbon
Energy that is generated onsite and used onsite at the time of generation.	There are no operational carbon emissions.
Energy that is generated onsite but not used at the time of generation, and is therefore exported to the grid. For the purposes of the WLCA, it is assumed that this is reimported at a different time in the year, so the carbon benefit is captured in the WLCA.	There are transport and distribution losses associated with using the electricity grid.
Additional energy that is generated in excess of the annual energy consumption of the building and exported to the grid.	Direct emissions of the grid that are being displaced are shown as a benefit in D2.

Table H4: Categories of onsite renewable energy generation

The following scenarios show the scope of the carbon factors used, depending on the category of the renewable energy generation.

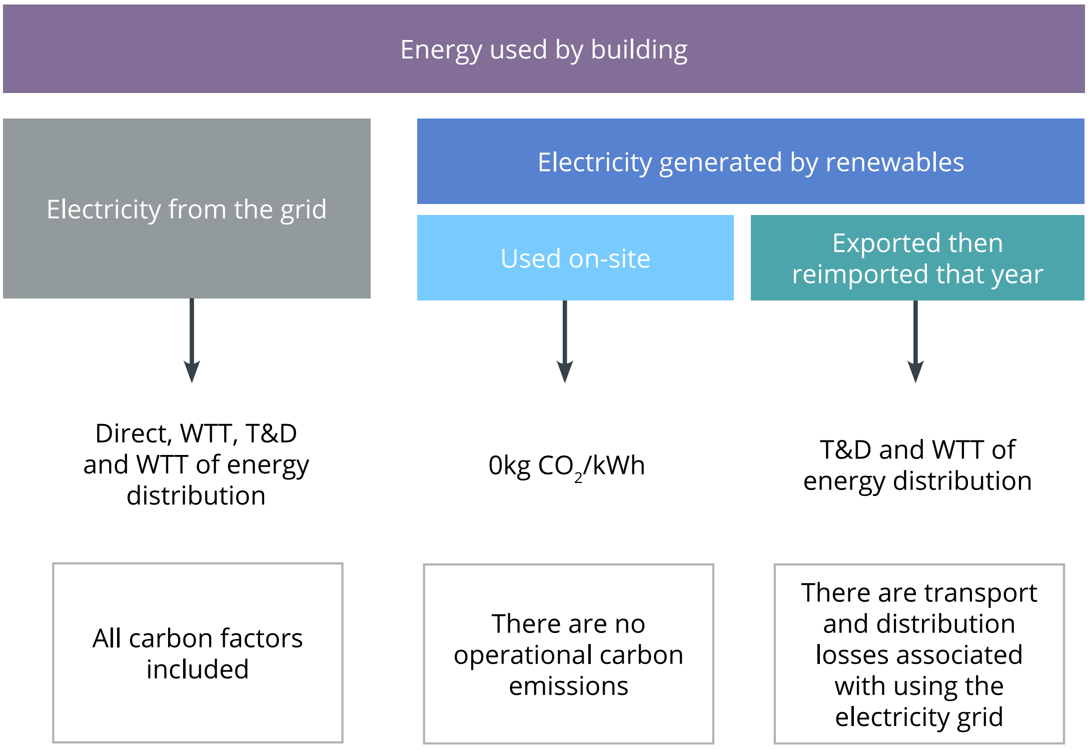


Figure H1: Annual renewable energy generation is less than annual energy use

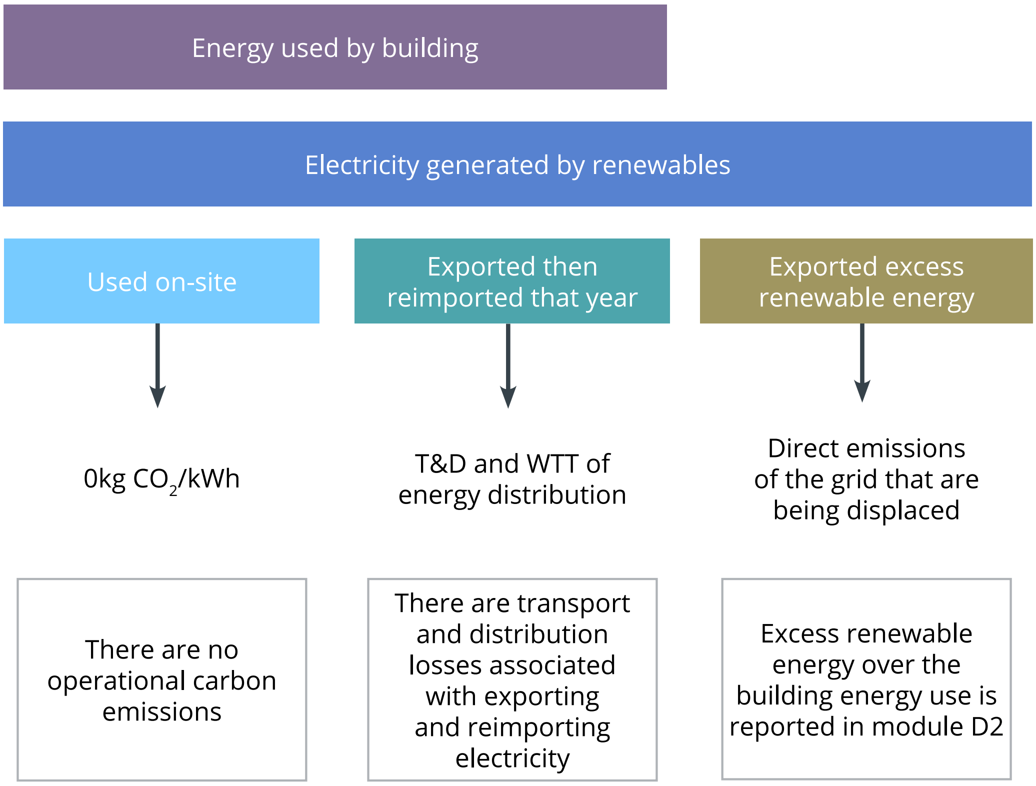


Figure H2: Annual renewable energy generation is greater than annual energy use

H4.3 Calculating renewable energy that is generated onsite and used onsite

Where possible, annual hourly renewable energy generation and electricity demand predictions should be assessed. The difference between electricity generated and electricity demand is then calculated for each hour. All net hourly exports should then be combined, which gives the annual exported electricity. The value of the annual renewable energy used on-site can be calculated by subtracting the annual exported electricity value from the annual renewable energy generation value.

Where detailed annual predictions are not possible, the proportions specified in Table H6 can be used for built assets without batteries. The proportion of annual onsite renewable electricity that is used directly by the building is determined by the proportion of energy used by the building that is generated by renewables over the course of a year.

Total energy used by the asset	Energy generated by renewables		
Percentage of total energy used by the asset generated by renewables over the course of a year	Percentage used onsite at time of generation	Percentage exported at time of generation, then used again by the asset over the course of a year	Net export over the course of a year
140%	30%	40%	30%
100%	40%	60%	0%
50%	60%	40%	0%
10%	100%	0%	0%

Table H6: Assumptions on the proportion of renewable energy generated onsite that is used by the asset (when there are no batteries installed as part of the renewables system), based on calculations by Feilden Clegg Bradley Studios

If an asset generates more renewable energy than it uses over the course of the year, this ‘additional’ electricity is not accounted for in A1–C4. It is captured in module D2, as suggested in EN 15978 (see section 4.8).

If an asset is using batteries, the embodied carbon of the batteries should be included in the building WLCA.

H5 Treatment of district heating networks

H5.1 Embodied carbon of district heating networks

In the first instance, obtain a value for the embodied carbon per kWh of delivered heat from the district heating network operator. Where this is not possible, a generic value of 0.02 kgCO_2/kWh heat can be assumed (see this EPD from Kraftringen Energi AB). These emissions should be accounted for in B6.

When assessing the embodied carbon of a heating network, district heating network operators should include all equipment for heat generation and distribution up until the plate heat exchangers of the buildings that are connected to the network. This should include, but not be limited to, the embodied carbon relating to the earthworks for installing distribution pipework, distribution pipework and insulation material, heat generation equipment, thermal stores, ancillaries and distribution pumps.

Where the heating network makes use of waste heat from a process, the embodied carbon of the process that generates the waste heat does not need to be included in the assessment. However, the embodied carbon of all distribution and ancillary equipment up until the customer's plate heat exchanger should be accounted for.

In cases where a combined heat and power (CHP) system is providing heating to the network, the entire embodied carbon of the CHP system should be accounted for in the embodied carbon calculation.

H5.2 Operational carbon of district heating networks

The operational carbon of district heating networks needs to be calculated using the same carbon factors as heat generation inside the building, so that they can be compared/understood on a like-for-like basis. The B6 carbon factor should include heat lost in distribution up to the building's plate heat exchanger.

It is suggested that a district heating network operator provides a set of carbon conversion factors for a typical RSP (decarbonised and non-decarbonised) that aligns with the scope outlined in carbon conversion set 1. The operator should also outline the assumptions that are used to calculate the carbon conversion factors, so that bespoke calculations can be carried out if the analysis has a different RSP.

Appendix I Carbon conversion factor sets for operational energy

Three carbon conversion factor sets have been developed. The carbon conversion sets are found on the 'Carbon conversion sets – generic' tab of the Energy – supplementary tables supporting document. In the case of the UK with an RSP of 60 years, see the 'Carbon conversion sets – UK' tab instead.

For emissions associated with energy use (module B6), different sets of carbon conversion factors should be used, depending on the project phase and the intent of the assessment:

- set 1 for design decision-making
- set 2 for reporting and benchmarking over the RSP, and
- set 3 for annual in-use reporting.

I1 Set 1: WLC design decision-making

For WLCAs to support design decision-making over the RSP, set 1 is provided. The relationship between embodied carbon and operational carbon changes significantly, depending on the decarbonisation assumptions of the electricity grid. Therefore, three scenarios have been developed:

- **Scenario (A) non-decarbonised (mandatory)**
- **Scenario (B) decarbonised (mandatory)**
- Scenario (C) net-zero-grid-compatible (optional)

In the WLCA, a non-decarbonised scenario (A) and a decarbonised scenario (B) must be calculated. In addition, to understand the WLC consequences of design decisions (e.g. additional insulation or different heating system types), a net-zero-grid-compatible scenario can be used to reflect the broader impacts on the wider electricity grid.

I1.1 Net-zero-grid-compatible carbon factor

The net-zero-grid-compatible carbon factor requires a local energy limit that has been developed and is aligned with the remaining carbon budget, as well as other actions needed by the built environment to deliver decarbonisation in line with a 1.5-degree pathway.

This method should only be applied to buildings that solely use electricity and no other fuel sources.

The carbon factor is split into two factors:

- a decarbonised carbon factor applied to the electricity consumption that is below the energy limit, and
- a non-decarbonised carbon factor applied to electricity above the limit.

This concept is shown in Figure I1.

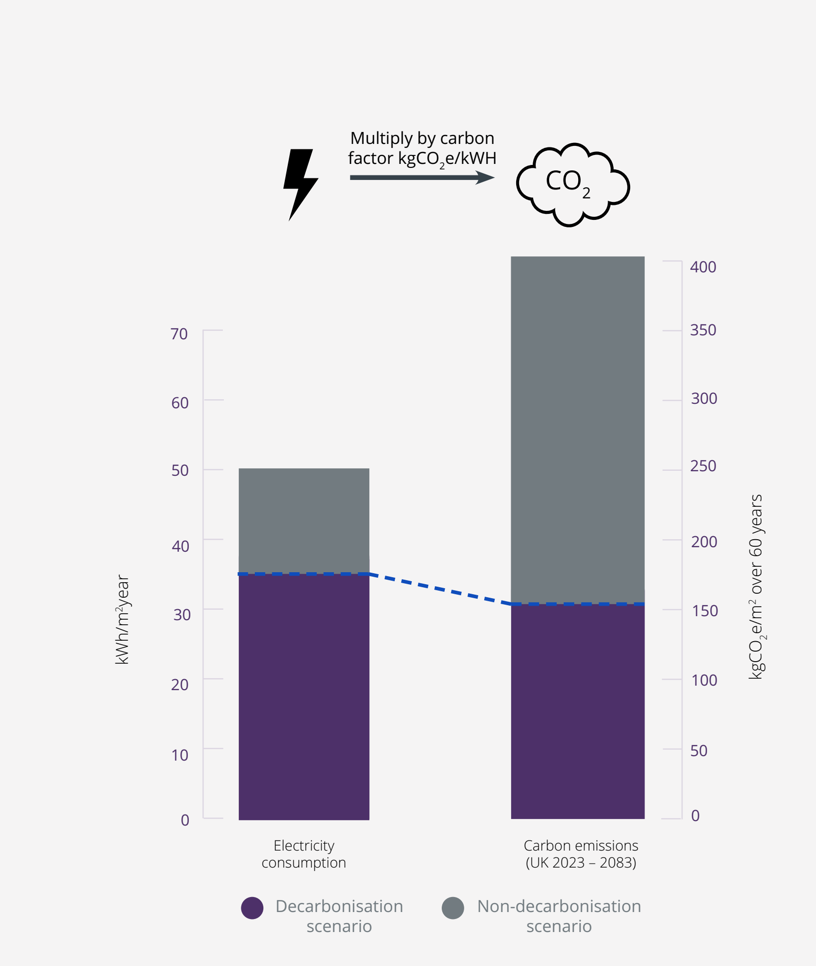


Figure I1: The net zero-compatible grid carbon factor (source: Introba)

This acknowledges that every built asset needs to play its part and assist grid decarbonisation in an equitable way. Therefore, assets that use more than their ‘fair share’ of energy cannot recognise the full benefit of the decarbonised grid, as they are not actively supporting the grid to decarbonise. This enables evaluation of design decisions that affect embodied carbon and operational carbon, while also representing the wider electrical grid impact.

For more information on the development of this approach, see the LETI Operational Carbon in Whole Life Carbon Assessments opinion piece.

I1.2 Hourly carbon factors

In addition to previous three scenarios, where predicted hourly carbon factors are available, these can be used to provide extra context during design decision making, particularly on the overall impact of energy storage or demand-side measures, but should not be used in formal reporting.

I2 Set 2: WLC benchmarking

To enable direct comparison between projects, when reporting the expected WLC figures for a project over the RSP, set 2 should be used. **In the WLCA, a non-decarbonised scenario (A) and a decarbonised scenario (B) must be calculated.**

Onsite renewable energy generation should be included in set 2. Predictive energy modelling can be used to make assumptions on the proportional split; if not available, use the assumptions set out in Appendix H.

I3 Set 3: annual reporting

The carbon conversion factors from set 3 should be used for annual reporting purposes, in order to establish how much carbon is associated with module B6 for a given year. As an alternative to the carbon accounting approach based on annual energy usage, an hourly carbon accounting approach can be taken where both hourly carbon and energy usage data is available.

For onsite renewables, the proportion of renewable energy that is generated onsite and used by the building should be based on meter readings. If meters do not capture this, predictive energy modelling can be used to make assumptions on the proportional split. If this is not available, use the assumptions in Appendix H.

Note that the scope of the carbon conversion sets is different to PCAF, GRESB and CRREM, which are used for corporate reporting, as they only include scope 1 and 2 emissions. They do not include well-to-tank (WTT), transmission and distribution (T&D) or the embodied carbon of infrastructure. Depending on the purpose and framework of annual reporting, different scopes can be used to ensure consistency with the relevant reporting framework.

Appendix J Energy metering

This appendix provides guidance on how to meter the various energy uses in a building, so that they can be reported in line with Table 20 in section 5.3.2 for non-residential and residential assets.

J1 General guidance on metering

Extensive metering and trend analysis can assist with finding faults in systems and fine-tuning energy use. NABERS has useful guidance, summarised as follows.

- **Accurate interval metering:** it is recommended that energy is metered in 15-minute intervals.
- **Match the energy model:** meter systems in line with a dynamic energy simulations model that closely predicts actual operational performance.
- **Understand system performance** by setting up hourly trend logs for all major pieces of MEP equipment, as these will be high energy consumers.

To achieve best practice, sub-metering could lead to a large number of dedicated distribution boards in order to split the load. Alternatively, metering at the breaker level could be adopted, which may require slightly larger boards to accommodate a potential size increase for the breaker.

J2 Non-residential metering guidance

The 'Metering – non-resi' tab in the Energy – supplementary tables supporting document provides guidance on energy metering, including the minimum standard, the recommended approach and best practice.

J3 Residential metering guidance

For residential buildings, it is not expected that different energy uses will be sub-metered; rely on incoming utility metering instead. However, it is important to be able to understand the total building use, separated from any renewable energy generation onsite and any EV charging. For residential buildings where energy consumption will be investigated further, it is recommended, as a minimum, to meter hot water demand, space heating demand, heating and hot water consumption, ventilation, lighting and plug loads.

Appendix K Module D1 examples for steel, timber and concrete (normative)

K1 Module D1 calculation

The equation and definitions in this appendix are taken from EN 15804:2012+A2:2019 and describe the calculation of module D1. Note that this is a net flow calculation, where only new primary materials are considered to have the potential for a benefit. The limitations of this approach are described in section 5.7.1.

$$\text{Module [D1]} = [M_{\text{MR out}} - M_{\text{MR in}}] \times ([E_{\text{MR after EoW out}}] - ([E_{\text{VMSub out}}]^{*} [Q_{\text{R out}}/Q_{\text{Sub}}]))$$

- $M_{\text{MR out}}$: Amount of material exiting the system that will be recovered (recycled and reused) in a subsequent system. This amount is determined at the end-of-waste point and is therefore equal to the output flow of 'materials to recycling [kg]' reported for modules A4, A5, B and C.
- $M_{\text{MR in}}$: Amount of input material into the product system that has been recovered (recycled or reused) from a previous system (determined at the system boundary).
- $E_{\text{MR after EoW out}}$: Specific emissions and resources consumed, per unit of analysis, arising from the material recovery (recycling and reusing) processes of a subsequent system after the end-of-waste state.
- $E_{\text{VMSub out}}$: Specific emissions and resources consumed, per unit of analysis, arising from acquisition and preprocessing of the primary material, or average input material if primary material is not used, from the cradle to the point of functional equivalence where it would be substituted for secondary material, which would then be used in a subsequent system.
- $Q_{\text{R out}}/Q_{\text{Sub}}$: Quality ratio between outgoing recovered material (recycled and reused) and the substituted material.

K2 Module D1 steel examples

K2.1 Example 1a: 1t of primary steel reused as 1t of secondary steel

In this example, we assume 1t of structural steel is recovered from the asset and directly reused.

$M_{MR\ out}$	$M_{MR\ in}$	Net output flow	$E_{MR\ after\ EoW\ out}$	$E_{VMSub\ out}$	Avoided impacts (per kg)	$Q_{R\ out}/Q_{Sub}$ (value correction factor)	Module D1
1t	0t	1t	0.2 $kgCO_2e/kg$	2.5 $kgCO_2e/kg$	-2.3 $kgCO_2e/kg$	1	-2300 $kgCO_2e$

Table K1: Net flow – steel, example 1a

K2.2 Example 1b: 1t of primary steel recycled as 0.95t of secondary steel

In this example, we assume that 0.95t of steel is recovered from an original 1t of primary steel that is in the asset.

$M_{MR\ out}$	$M_{MR\ in}$	Net output flow	$E_{MR\ after\ EoW\ out}$	$E_{VMSub\ out}$	Avoided impacts (per kg)	$Q_{R\ out}/Q_{Sub}$ (value correction factor)	Module D1
0.95t	0t	0.95t	0.5 $kgCO_2e/kg$	2.5 $kgCO_2e/kg$	-2.0 $kgCO_2e/kg$	1	-1900 $kgCO_2e$

Table K2: Net flow – steel, example 1b

K2.3 Example 1c: 1t of steel with 50% recycled content, recycled as 0.95t of secondary steel

This example is the same as 1b, except that the steel in the asset has 50% recycled content.

$M_{MR\ out}$	$M_{MR\ in}$	Net output flow	$E_{MR\ after\ EoW\ out}$	$E_{VMSub\ out}$	Avoided impacts (per kg)	$Q_{R\ out}/Q_{Sub}$ (Value correction factor)	Module D1
0.95t	0.5t	0.45t	0.5 $kgCO_2e/kg$	2.5 $kgCO_2e/kg$	-2.0 $kgCO_2e/kg$	1	-900 $kgCO_2e$

Table K3: Net flow – steel, example 1c

K3 Module D1 timber examples

The calculation of module D1 with respect to timber is linked to the end-of-life recovery or disposal processes that have been modelled, and the treatment of biogenic carbon.

The treatment of timber to be reused, recycled or recovered as a secondary fuel is essentially the same as other materials, but the transfer of sequestered biogenic carbon to the reused product, recycled product or secondary fuel in the next product system must be considered.

To represent this transfer, all sequestered carbon in timber that is reused, recycled or recovered as a secondary fuel must be included in C3 as an emission of CO_2, and as a corresponding removal of CO_2 in D1.

For the primary product or fuel that these outputs substitute in D1, the process emissions and the sequestered carbon, as a removal of CO_2, are both included as the avoided impacts in D1. Where biomass products are substituted like-for-like, this normally cancels out the sequestration in D1.

Where the timber or biomass is used for energy recovery in a facility with R1 status, incinerated in a facility without R1 status or landfilled with landfill gas capture, the benefit of any recovered energy production is included in D1.

K3.1 Example 2a: 1t of primary softwood timber is recovered and reused as 0.95t of secondary softwood timber

This example assumes a notional 100 $kgCO_2e$/tonne of emissions associated with post-recovery processes ($E_{MR\ after\ EoW\ out}$).

$M_{MR\ out}$	$M_{MR\ in}$	Net output flow	$E_{MR\ seq}$	$E_{MR\ after\ EoW\ out}$	$E_{VMSub\ out}$	$E_{VMSub\ seq}$	Avoided impacts	Value correction factor	Module D1 avoided impacts and sequestration
0.95t	0.0t	0.95t	-1.530 $kgCO_2e$/kg	0.100 $kgCO_2e$/kg	0.263 $kgCO_2e$/kg	-1.530 $kgCO_2e$/kg	-0.163 $kgCO_2e$/kg	1	-154.85 $kgCO_2e$

Table K4: Net flow – timber, example 2a

K3.2 Example 2b: 1t of primary timber is recovered and recycled as 0.95t of chips for use in particleboard

This example assumes no distinction between the sequestered carbon in primary and secondary wood chips. There is a difference in emissions associated with processing end-of-life timber into chips and processing primary wood chips for use in particleboard production, because the primary woodchips will also include the impacts of forestry and harvesting.

$M_{MR\ out}$	$M_{MR\ in}$	Net output flow	$E_{MR\ seq}$	$E_{MR\ after\ EoW\ out}$	$E_{VMSub\ out}$	$E_{VMSub\ seq}$	Avoided impacts	Value correction factor	Module D1 avoided impacts and sequestration
0.95 t	0.0 t	0.95 t	-1.530 $kgCO_2e/kg$	0.455 $kgCO_2e/kg$	0.500 $kgCO_2e/kg$	-1.530 $kgCO_2e/kg$	-0.045 $kgCO_2e/kg$	1	42.75 $kgCO_2e$

Table K5: Net flow – timber, example 2b

K3.3 Example 2c: 1t of primary timber is incinerated with energy recovery in an energy from waste (EfW) plant with R1 status

Where timber is recovered for incineration, there are process emissions associated with the preparation of the timber for incineration and those associated with its combustion. These are both captured in C3 if the incinerator R1 efficiency factor is greater than 60%, or in C4 if it is less than 60%. The benefit of generating energy from the incinerated timber is captured in D1; this is not to be confused with onsite export of renewable energy, which is captured in D2.

The benefit of energy generated through the incineration of timber is typically electrical energy in the UK, although heat can also be recovered. The benefit to be reported in D1 is associated with the displacement of the emissions associated with alternative energy production. Depending on the project, this will also be highly dependent on the decarbonisation assumptions associated with the supply of alternative energy.

$M_{INC\ out}$ (t)	$X_{INC\ elec}$ (kWh/t)	$E_{SE\ elec}$ ($kgCO_2e/kWh$)	Module D1
1.0	1050	0.193	-203 $kgCO_2e$

Table K6: Timber energy recovery, considering electrical energy only

- $M_{INC\ out}$ is the mass of timber to be incinerated, after processing.
- $X_{INC\ elec}$ is the electrical energy generated per tonne of timber for waste wood plants with R1 efficiency factor above 60% (source: Tolvik UK Dedicated Biomass Statistics – 2019).
- $E_{SE\ elec}$ is the carbon factor of UK grid electricity production.

K4 Module D1 concrete examples

K4.1 Example 3a

1t of precast concrete is deconstructed, leading to 0.9t of reused precast concrete after excluding the rebar.

$M_{MR\ out}$	$M_{MR\ in}$	Net output flow	$E_{MR\ after\ EoW\ out}$	$E_{VMSub\ out}$	Avoided impacts (per kg)	$Q_{R\ out}/Q_{Sub}$ (value correction factor)	Module D1
0.9t	0t	0.9t	0.0 $kgCO_2e$/kg	0.2 $kgCO_2e$/kg	-0.2 $kgCO_2e$/kg	1	-180 $kgCO_2e$

Table K7: Net flow – concrete, example 3a

K4.2 Example 3b

1t of in situ concrete is demolished, leading to 0.95t of crushed concrete recycled as road base and 20kg steel scrap. Rebar is assumed to be 90% recycled content.

$M_{MR\ out}$	$M_{MR\ in}$	Net output flow	$E_{MR\ after\ EoW\ out}$	$E_{VMSub\ out}$	Avoided impacts (per kg)	$Q_{R\ out}/Q_{Sub}$ (value correction factor)	Module D1
Concrete 0.95t	0t	0.95t	0.001	0.005	-0.004	1	-3.8 $kgCO_2e$
Rebar 0.02t	0.018t	0.002t	0.500*	0.684	0.184	1	-0.368kg

Table K8: Net flow – concrete, example 3b

* Assume electric arc furnace (EAF) energy intensity to return to supply.

Appendix L European and industry standards relating to WLCAs

Table L1 provides an overview of the key standards referred to in this standard, giving their full titles and regional jurisdiction.

Standard	Full title	Regional jurisdiction
EN 15978: 2011	Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method	European standard. This standard is currently under revision and is expected to be republished in 2024.
prEN 15978-1:2021	Sustainability of construction works – Methodology for the assessment of performance of buildings – Part 1: Environmental Performance	Enquiry draft of revision to European standard EN 15978:2011, providing an indication of future standardisation of building-level life cycle assessment.
EN 17472:2022	Sustainability of construction works – Sustainability assessment civil engineering works – Calculation methods	European standard
EN 15804:2012 + A2: 2019	Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products	European standard
EN 15643:2021	Sustainability of construction works — Framework for assessment of buildings and civil engineering works	European standard
FprEN 15941:2023	Sustainability of construction works — Data quality for environmental assessment of products and construction work - Selection and use of data	Final enquiry draft of European standard providing an indication of future standardisation of data quality

Standard	Full title	Regional jurisdiction
PAS 2080:2023 and Guidance Document for PAS 2080	Carbon management in buildings and infrastructure	BSI publicly available specification and associated guidance
CIBSE TM65 (2021), including 2022 addendum	Embodied carbon of building services: a calculation methodology	CIBSE technical memorandum – free for CIBSE members
EN 16449: 2014	Wood and wood-based products — Calculation of the biogenic carbon content of wood and conversion to carbon dioxide	European standard

Table L1: Key standards referred to in this standard

Other relevant standards are included in Appendix Q.

Appendix M Standardised approach to creating elemental build-ups

When using BIM or other 3D software to generate the volume of material for the early-stage analysis of elements, quantify all components, including those not usually modelled in BIM software. This includes components such as secondary support, studwork, bracketry, window/door frames and glazed panels.

The following is the suggested approach for creating build-ups per m^2 of element:

1. Test by drawing up the element as a detailed elemental study. Use the manufacturer's details/accurate quantities to draw a 1m x 1m 'element' and get an element figure per m^2 for each material. Be careful to account for void spaces and mixed materials (e.g. the brick and mortar in brickwork), as shown in the following example.
2. For materials that are included at given spacings, such as timber or metal studwork, calculate the average number of studs per m^2, as shown in the following example.
3. Record the densities of each material so that the mass of each can be calculated.
4. If using life cycle assessment software and/or applying a material or carbon factor, make sure that the declared unit for the carbon factor (mass, volume, area, etc.) correctly links to the quantity of the material in the element. For example, the impact for plasterboard may be given per m^2 rather than per kg.
5. Create a library of these bespoke elemental studies, recording the percentage breakdown by volume of each material per element.

An example of this approach is provided in Figure M1 for an external wall, with the quantities shown in Table M1.

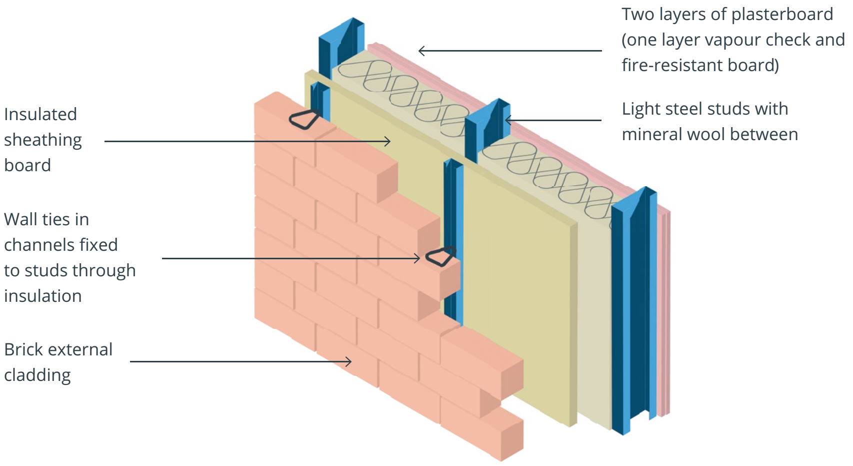


Figure M1: Elemental build-up for an external wall (reproduced with permission from SteelConstruction.info)

Materials	Specification	Quantity per m²	ECO$_2$e data per	Material per m²
100mm brickwork	18% mortar	0.018m³ mortar	m³	0.018m³ mortar
	82% brick @ 1700kg/m³	0.082m³ brick	kg	1394kg bricks
Light steel supports	Galvanised steel at 500mm centres	2 linear metres of galvanised steel @ 3.3kg/m	tonne	0.0066 tonnes of galvanised steel
Insulated sheathing board	20mm polyurethane (PU) @ 35kg/m³	0.02 m³ @35kg/m³	kg	0.7kg PU insulation
Light steel studs	Galvanised steel @ 500mm centres	2 linear metres @ 6.5 kg/m	tonne	0.013 tonnes galvanised steel
Mineral wool insulation	200mm stone wool @ 50kg/m³ between studs	0.2m³ @ 50kg/m³	kg	10kg stone wool
Plasterboard	12.5mm vapour-check plasterboard	1m² @12.5mm	m²	1m² 12.5mm vapour-check plasterboard
	12.5mm fire-resistant plasterboard	1m² @12.5mm	m²	1m² 12.5mm fire-resistant plasterboard

Table M1: Elemental build up for 1m² of external wall shown in Figure M1

Appendix N Biogenic carbon

N1 Recovered biomass, including reused or recycled biomass

Recovered biomass is considered to contain sequestered biogenic carbon, just like virgin biomass, transferred from the previous product system. It is not necessary to consider whether the original biomass (in its first use) was sustainably sourced when considering this.

Therefore, when reused or recycled biomass is used in a building or infrastructure asset, the sequestered carbon is treated in exactly the same way as sustainably sourced virgin timber or biomass: as a removal of biogenic CO_2 in modules A1–A3. At end of life, the sequestered carbon is emitted or transferred to the next product system and is considered as an emission of biogenic CO_2, as with sustainably sourced virgin timber and biomass. Therefore, recovered biomass has a biogenic carbon balance over the asset's life cycle.

N2 Calculating the sequestered carbon stored in an asset

EPDs that comply with EN 15804+A2 are required to report their total climate change impacts split into fossil, biogenic and LULUC carbon for each module. In addition, they are required to report the mass of sequestered carbon (as 'kg carbon', not CO_2) in both the product and any packaging if it is more than 5% of their respective masses. The mass of carbon can be converted to the mass of CO_2 by multiplying by 44/12 (relative atomic mass of carbon = 12g; relative atomic mass of oxygen = 16g).

EPDs that comply with EN 15804+A2 are also required to report modules C and D. However, the end-of-life scenarios provided in EPDs must always be checked to ensure they align with the defaults provided in section 5.6, as end-of-life routes for biomass vary considerably in different countries, as do the benefits of energy recovery due to different incinerator efficiencies, take-up of heat recovery and different electricity and heat mixes in module D. If the scenario is not aligned, modules C and D must be generated using the reported biogenic carbon content and the default scenarios.

EPDs that comply with EN 15804+A1 were not required to report biogenic carbon separately, or to report the mass of sequestered carbon in the product or packaging, although some did. In most cases, they included the sequestered carbon as a removal in modules A1–A3; however, in some programmes this is not allowed if the end-of-life stage is not reported. **If an EPD does not report sequestered carbon, the quantity of sequestered carbon in the product must be calculated so this can be considered as part of the WLCA compliant with this standard. If the EPD voluntarily provides data for modules C and D, then as with EPDs that comply with EN 15804+A2, this must be checked to ensure it aligns with the defaults in section 5.6. If the scenario is not aligned or no scenario is modelled, modules C and D must be generated using the reported or calculated biogenic carbon content and the default scenarios.**

For solid timber and products containing timber, EN 16449 provides a rule of thumb that can be used to calculate or check the biogenic carbon content of the wood, which is that half the dry mass of wood is assumed to be biogenic carbon. By accounting for moisture and material like glues or resins contained within the product (which should be described in the EPD), the dry mass can be obtained in order to undertake this calculation. The mass of biogenic carbon can be converted to the mass of biogenic CO_2 sequestered in the product by multiplying by 44/12.

For other biomass, the sequestered biogenic carbon content needs to be considered for the specific material. If this is not reported, TNO's Phyllis database provides details of the biogenic carbon content for a wide range of biomass. Product content and stoichiometry can also be used if the molecular nature of the biomass is known, or there are test methods such as those provided in EN 16785-1.

N3 Reporting the benefits of carbon storage

Using biobased products in other long-life products within buildings provides a benefit because the biogenic carbon sequestered within them means that carbon is stored out of the atmosphere for a much longer period than if the biomass was used for energy or short-lived products like paper. The increasing stock of biogenic carbon within forests, and within harvested wood products like structural timber and wood-panel products used in buildings and furniture, are recognised by countries as a benefit in their national carbon accounts. These accounts are provided using standard Intergovernmental Panel on Climate Change (IPCC) methods as part of the Paris Agreement to track progress in reducing GHG emissions and limiting climate change to less than 1.5°C. The longer biogenic carbon can be stored out of the atmosphere, the more benefit it provides. It is therefore better – not just for the circular economy but for global warming – to extend the life of biobased products, and to reuse and recycle them at end of life, rather than use them for energy recovery or dispose of them with incineration or in landfill. The following approaches allow the benefit of long-term carbon storage, and potentially the reuse and recycling of biomass at end of life, to be quantified and reported.

PAS 2050:2011 allows the benefits of permanent and/or temporary carbon storage to be accounted for, for a period of up to 100 years from manufacture to the point of incineration or recovery (whichever is earlier), weighted by the number of years out of 100 that biogenic carbon is stored and the percentage of the biogenic carbon that is stored. Footprints calculated according to PAS 2050:2011 can deduct the calculated impact of carbon storage from the total GHG impact over the life cycle of the built asset. It should be noted that the PAS 2050 method does not show any greater benefit if biomass is reused or recycled at the end of life, rather than combusted with possible energy recovery. For a building with a 60-year required service life, whatever the fate of the timber at end of life, 60% of the carbon sequestered within the building over 60 years could be claimed as the calculated benefit of carbon storage over the 100-year period used by PAS 2050.

A more detailed approach to facilitate the assessment of the dynamic climate effects (integrated radiative forcing and temperature change) caused by a temporally-resolved (year-by-year) inventory of GHGs (CO_2, CH_4 and N_2O) was developed by Cooper (2020), who provides a spreadsheet that calculates and graphically displays the radiative forcing and temperature change associated with removals and emissions of key GHGs each year, over a given time period of up to 500 years. This approach can be used to compare building options with different temporal emission profiles, as shown in Hawkins et al., 2021.

Hawkins et al. use a 'forward looking' approach to account for the sequestration of carbon over a 50-year period from the point of harvest, rather than a 'backward looking' or 'year 0' approach. This standard recommends carbon sequestration is accounted for in the year of harvest (a year 0 approach), as per the EN 15804 and TC 350 standards. At end of life, the benefit of further carbon storage if products are reused or recycled could be explored relative to combustion with possible energy recovery.

The French *Regulation of building-related carbon emissions* requires in the Arrêté of 4th August 2021 (Ministère de la transition écologique, 2021) both the reporting of biogenic carbon storage (in kg carbon/m^2), and the use of the same dynamic approach to calculating the overall impact of the building, by providing simplified weighting factors ('les coefficients de pondération' provided in Article 11 of the Arrêté) based on IPCC radiative forcing, to be applied to net emissions or removals in each of the 50 years studied, in order to show the relative impact assuming an emission in Y0 has 100% impact and an emission in Y100 has no impact. This means that emissions and removals that occur earlier in the asset life cycle have greater weighting in the overall impact than those that occur later in the life cycle. This approach only provides weighting factors for the first 50 years of an asset's life, as the French Regulation uses an RSP of 50 years. It does not allow longer life cycles, or the benefit of reuse or recycling at the end of an RSP of 60 years, to be considered. It is expected that the revision of EN 16485:2013, the CEN c-PCR for timber, will provide weighting factors for up to 100 years from construction, which could then be used to calculate the benefit of carbon storage and reuse, and recovery of biomass at end of life, to be calculated over the full life cycle of the asset.

If users of this standard wish to explore the benefits of biogenic carbon storage in their assessments, it is suggested that as additional information, the impact including the benefit of biogenic carbon storage could be reported using the approach of either PAS 2050:2011 or the latest revision of EN 16485, or other recognised approaches, with the approach used clearly reported. Additionally, where different options are being compared, the spreadsheet from Cooper (2020) could be used to review and report the integrated radiative forcing (W-yr/m^2) and temperature change (delta-K) over a 100-year timeframe, by entering the year-by-year net removals or emissions from an assessment for each option (as described in Hawkins et al., 2021).

Appendix O Material decarbonisation scenario

The decarbonisation scenario for materials does not take into account the use of carbon capture and storage, as temporary carbon storage and permanent biogenic carbon storage cannot be considered in EN 15804. Permanent carbon capture and storage and carbon capture and usage should not be considered until modelling rules have been developed for EN 15804, in order to avoid double counting.

In addition, material efficiency measures such as reducing the amount of materials required for the structure of a building, or sufficiency measures such as reducing the need for new construction through greater refurbishment, will not impact use stage and end-of-life impacts, only those of new-build construction.

Decarbonisation roadmaps, such as the one provided by UKGBC for embodied impacts, account for all types of decarbonisation, including material efficiency and sufficiency, so will overestimate the potential for decarbonisation that can be considered in modules B, C and D. The UKGBC roadmap only addresses UK production, not the decarbonisation of imported products. For steel, for example, the IEA predict global emissions from the sector could rise based on stated policies, and at a maximum will only reduce by 54% by 2050, taking into account CCUS and material efficiencies. This compares with a 90% reduction assumed for UK steel in 2050 by UKGBC.

The IPCC provided an estimate of decarbonisation of embodied impacts for buildings globally, which separately accounted for material efficiency and sufficiency. Without these, but including CCUS, the maximum embodied carbon decarbonisation by 2050 would be 64%.

Recent progress with decarbonisation in the construction products sector has been slow. For example, brick and cement have both reported relatively stable emissions intensity in the UK for the last decade, following several decades of reductions. Although some sectors have produced optimistic roadmaps to 2050, many of the measures are not yet tested or proven at a large scale, and many sectors both in the UK and internationally have not published decarbonisation roadmaps. Reductions after 2050 are even more uncertain.

The decarbonisation of WLC is included in this standard to enable users to understand how impacts may change in the future. The scenarios for embodied carbon decarbonisation are very uncertain, and likely to vary for different materials and sources. For this reason, a default factor of 50% has been chosen for most embodied impacts (although not all), in order to reflect potential reductions while not requiring considerable work for assessors to review decarbonisation roadmaps for different materials and countries.

Appendix P Landlord/tenant and owner-occupier scopes for offices

There are two main types of office asset: landlord/tenant and owner-occupier. An owner-occupier is responsible for all emissions at all life cycle stages of the asset. For a landlord/ tenant asset, who is usually responsible is different for each life cycle stage of the WLCA, and is shown in Table P1.

Boundaries	**Landlord or tenant**	**Landlord only**	**Tenant only**
Upfront carbon (A1–A5)		Shell and core/Cat A	Cat B
Operational carbon (B6–B8)	Operational carbon created in areas of the asset belonging to either party		
In-use embodied carbon (B1–B5)	In-use embodied carbon created in areas of the asset belonging to either party		
End-of-life embodied carbon (C1–C4)		Shell and core/Cat A	Cat B
Module D		Shell and core/Cat A	Cat B

Table P1: Landlord/tenant emissions split

When producing a WLCA report, while not mandatory, it can be useful to split the emissions based on the landlord/tenant relationship to ensure each party understands their obligations to control emissions and identify potential reductions. Table P2 gives an example of how this might break down in accordance with the reporting templates. It is likely there will be a number of overlapping categories.

	Structural and architectural	Mechanical	Public health/life safety	Electrical	Other
Shell and core	Primary structure and thermal envelope 0.1 Treatment and demolition works 1 Substructure 2.1 Frame 2.2 Upper floors 2.3 Roof 2.4 Stairs and ramps 2.5 External envelope, including roof finishes 2.6 Windows and external doors 2.7 Internal walls and partitions 2.8 Internal doors 3 Finishes 4 FF&E, including fixed units in central areas, kitchen and special equipment for provision of centralised building services like laundry and delivery rooms, and IT/AV/audio that serves the whole building 7 Works to existing buildings, including repairs 8 External works	Centralised plant and supply and distribution to common/landlord areas like circulation/toilets in central core/car park/lift shafts: 5.2.1.1 Heat and hot water generation equipment, including plate heat exchanger that connects to a district heating network 5.2.1.2 Heat and hot water distribution, control, ancillaries, emitters, exchangers/terminal units 5.2.2 Cooling generation and central ventilation distribution 5.2.3 Central air handling equipment 5.2.4 Central ventilation distribution and control 5.5.2 Fuel installations	Centralised supply systems and distribution to landlord areas like circulation/toilets/car park/lift shafts: 5.1.1 Sanitaryware for common area, e.g. toilets and cleaners' cupboards 5.1.2.1 Central distribution of potable water 5.1.2.2 Water tanks 5.1.3.1 Drainage stacks 5.1.3.2 Central water reuse and treatment systems 5.2.1.1 Domestic hot water heat generation and central distribution, pumps, ancillaries, storage and heat exchanger 5.5.1.1 Sprinkler system 5.5.1.2 Firefighting systems: risers, AOV, suppression, etc.	Centralised supply systems and distribution to landlord areas like circulation/toilets/car park/lift shafts: 5.3 Lift and conveyor installations 5.3.1 Lighting: internal, external, emergency and other 5.3.2.1 Electrical power, including supply, distribution, transformers/incoming power supply and high and low voltage switch gear 5.3.2.2 ELV/communications/security 5.3.2.3 IT and data 5.3.2.4 Building management system (primary elements, e.g. head end, main panels and outstations) 5.3.2.5 Electricity backup systems 5.3.2.6 Fire detection and alarm systems 5.4.1 On-site renewables and associated storage 5.5.1.3 Lightning protection/earth bonding	Centralised supply systems and distribution to landlord areas like circulation/toilets/car park/lift shafts: 5.5.4 Specialised and communal waste disposal 5.5.5 Specialist installation and maintenance 5.5.6 Builders work in connection with services

	Structural and architectural	Mechanical	Public health/life safety	Electrical	Other
Cat A	Occasionally Cat A works for tenants may require primary structural work, e.g. to connect floors. More frequently, landlord works within tenanted areas is likely to include: 2.7 Internal walls and partitions 2.8 Internal doors 3 Finishes 4 FF&E, dependent on lease agreement, e.g. fixed units, kitchen and special equipment for provision of turnkey tenant areas, IT/AV/audio 7 Works to existing buildings, including repairs 8 External works, if tenant areas include dedicated external space	Plant and systems provided by the landlord in tenanted areas: 5.2.1.1 Heat and hot water generation equipment if in tenanted area 5.2.1.2 Heat and hot water distribution, control, ancillaries, emitters, exchangers/terminal units 5.2.2.2 Cooling emitters, exchangers/terminal units, ancillaries and control, distribution, storage 5.2.4 Ventilation ductwork, terminals, ancillaries and dampers	Plant and systems provided by the landlord in tenanted areas: 5.1.1 Landlord-provided sanitaryware to tenanted areas 5.1.2.1 Local distribution of potable water 5.1.2.2 Water tanks - localised 5.1.3.1 Drainage 5.5.1.1 Sprinkler distribution and heads	Plant and systems provided by the landlord in tenanted areas: 5.3.1 Lighting, including local emergency provision 5.3.2.1 Electrical power including distribution, sockets, etc. 5.3.2.2 Local ELV/communications/security 5.3.2.3 Local IT and data 5.3.2.4 BMS local panels, sensors and wiring 5.3.2.6 Local fire detection and alarm	Plant and systems provided by the landlord in tenanted areas: 5.5.6 Builders work in connection with services

	Structural and architectural	Mechanical	Public health/life safety	Electrical	Other
Cat B	Tenant modifications to on floor: 2.7 Internal walls and partitions 2.8 Internal doors 3 Finishes 7 Works to existing buildings including repairs 8 External works, if tenant areas include dedicated external space Tenant FF&E items: 4.1 General FF&E including built in units and general loose FF&E, fire extinguishers etc 4.2 Kitchen equipment including cooking (oven, hobs, fryers), fridges and freezers, dishwashers, washing machines 4.3 Special equipment, e.g. lab equipment 4.4 Loose FF&E 4.5 IT equipment including computer screens, computers, TV screens 4.6 Audio and visual equipment	Tenant modifications to on floor: 5.2.1.2 Heat & hot water distribution, control, ancillaries, emitters, exchangers/terminal units 5.2.2.2 Cooling emitters, exchangers/terminal units, ancillaries and control, distribution, storage 5.2.4.2 Ventilation ductwork, terminals, ancillaries and dampers Tenant installation of: 5.2.2 Tenant server room cooling system 5.3.2.5 Tenant generators and UPS	Tenant modifications to on floor: 5.1.1 Sanitaryware 5.1.2.1 Distribution of potable water 5.1.3.1 Drainage 5.5.1.1 Sprinkler distribution and heads	Tenant modifications to on floor: 5.3.1 Lighting, including local emergency provision 5.3.2.1 Electrical power including distribution, sockets, etc. 5.3.2.2 Local ELV/ communications/ security 5.3.2.3 Local IT and data 5.3.2.4 BMS local panels, sensors and wiring 5.3.2.6 Local fire detection and alarm Tenant installation of: 5.3.2.2 Hard-wired AV and audio systems 5.3.2.3 Tenant IT servers and distribution 5.3.2.5 Tenant standby generator and back up equipment	Tenant modifications to on floor: 5.5.6 Builders work in connection with services

Table P2: Example of how to categorise asset emissions for shell and core, Cat A and Cat B works

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