Embodied and whole life carbon assessment for architects

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This paper introduces architects to carbon assessment in the built environment and its application through the RIBA work stages. It makes the case for architects' role in reducing carbon emissions to mitigate climate change, explains the key concepts of embodied and whole life carbon and recommends the use of the Royal Institution of Chartered Surveyors (RICS) methodology for undertaking detailed carbon assessments (RICS Whole life carbon assessment for the built environment professional statement 2017). To date, this is the most comprehensive and consistent approach available to the industry.

Cover image: Google, London HQ at Kings Cross, London (under construction) © HayesDavidson. Architects: BIG, Heatherwick Studio, BDP. Carbon Consultant: Sturgis Carbon Profiling.

Google have included whole life carbon as a key performance indicator. This included detailed elemental analysis as well as an overall carbon budget and targets.

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Editor: Gesine Kippenberg
Chapter: Summary of RICS Whole life carbon assessment for the built environment professional statement (2017) © RICS

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Introduction

This paper introduces architects to carbon assessment in the built environment and its application through the RIBA work stages. It makes the case for architects' role in reducing carbon emissions to mitigate climate change, explains the key concepts of embodied and whole life carbon and recommends the use of the Royal Institution of Chartered Surveyors (RICS) methodology for undertaking detailed carbon assessments (RICS Whole life carbon assessment for the built environment professional statement 2017). To date, this is the most comprehensive and consistent approach available to the industry.

Increasingly, clients in all sectors are commissioning WLC assessments as part of the project requirements. This is primarily driven by environmental considerations but also makes economic sense. Important benefits of WLC assessments include: a better understanding of the sourcing and processing of materials and products; an understanding of long term post completion considerations such as maintenance, durability and lifespan; and making plain the carbon value of retaining existing built fabric.

Undertaking WLC assessments is recommended for all architects who wish to understand and minimise the carbon emissions associated with their designs over the entire life cycle of the building. The knowledge gained from WLC assessments further enables architects to take the lead in sustainable design and construction. Architects intending to undertake WLC assessments should also refer to the full RICS professional statement (RICS PS).

21 Moorfields, London. Architect: Wilkinson Eyre. Carbon Consultant: Sturgis Carbon Profiling.

This project by developer Landsec for occupier Deutsche Bank has included detailed whole life carbon assessments of design, supply chain and construction.

Carbon emissions and the built environment

Climate change in the 21st Century is projected to have severe detrimental consequences for the environment and societies world-wide. Caused by man-made greenhouse gas emissions, also referred to as carbon emissions, the challenge of today is to prevent further escalating temperatures. The Paris Agreement aims to limit global warming to well below 2°C with efforts made to limit it to 1.5°C.

This goal will only be achieved if carbon emissions in the built environment are reduced dramatically. According to the Green Construction Board, the sector currently generates some 35-40% of the total carbon emissions in the UK.

The following definitions of Scope 1, 2 and 3 emissions are taken from UK government's *Guidance on how to measure and report your greenhouse gas emissions.*

Under construction. Dalston Lane, London: Architects: Waugh Thistleton. Carbon consultants: Ramboll. Image © Daniel Shearing.

This project is a combination of a low carbon CLT structural frame, combined with a long life brick skin. Brick is a high carbon cost material to produce, however this is outweighed by extreme durability. A good example of a long life and low carbon typology.

After completion. Dalston Lane, London: Architects: Waugh Thistleton. Carbon Consultants: Ramboll.

Scope 1 (Direct emissions)

Activities owned or controlled by your organisation that release emissions straight into the atmosphere. These are direct emissions. Examples of scope 1 emissions include emissions from combustion in owned or controlled boilers, furnaces, or vehicles.

Scope 2 (Energy indirect)

Emissions being released into the atmosphere associated with your consumption of purchased electricity, heat, steam and cooling. These are indirect emissions that are a consequence of your organisation's activities but which occur at sources you do not own or control.

Scope 3 (Other indirect)

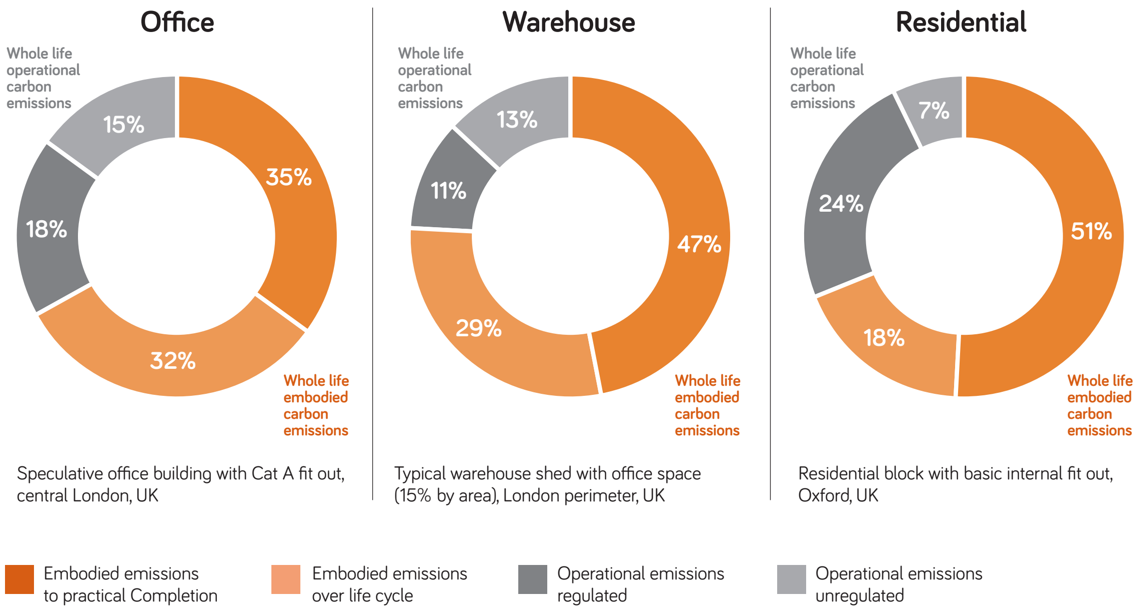
Emissions that are a consequence of your actions, which occur at sources which you do not own or control and which are not classed as scope 2 emissions. Examples of scope 3 emissions are business travel by means not owned or controlled by your organisation, waste disposal, or purchased materials.

Embodied carbon emissions

Embodied carbon emissions are included within scope 3, in that construction materials specified by architects are produced by other parties and would be counted as their scope 1 or 2 emissions. Whole life carbon in relation to a building covers scope 1, 2 and 3 emissions.

Carbon emissions in the built environment are therefore attributable to both the energy use of built assets (operational emissions) and to their construction and maintenance (embodied emissions). The construction process, including the sourcing of materials and their conversion into products, systems and buildings as well as transport and site works is a significant source of embodied carbon emissions. Post practical completion (PC), further materials are consumed through maintenance and replacement over a building's life (typically taken as 60 years).

Collectively, these emissions can exceed those from day to day operational energy use. They can also be cheaper, often cost neutral, to reduce.



Pie charts illustrating indicative relationships between operational and embodied carbon emissions for three building typologies. The whole life figures have been calculated in line with the modular structure (modules A-C) of BSEN15978 as detailed in RICS PS., i.e. over a 60 years life cycle. Operational and embodied emissions are as estimated at design stage. Grid decarbonisation applied to emissions due to electricity consumption over the life of the building in accordance with the slow progression scenario in National Grid Future Energy Scenarios 2015. Diagrams: Sturgis Carbon Profiling/ RICS.

Whole life carbon approach

To get a true picture of a building's energy and carbon emissions impact it is necessary to understand not only the operational and the embodied emissions on their own, but also the interrelationship between them. Whole life carbon (WLC) thinking therefore means considering these emissions together so as to optimise their relative and combined impacts and avoid the unintended consequences of assessing each in isolation. In summary, a low carbon building is one that optimises the use of resources both to build it and to use it over its lifetime.

Standards for whole life carbon assessment

The British Standard BS EN 15978:2011 sets out the overall principles of embodied and whole life carbon measurement in the built environment. BS EN 15978 covers the assessment of the environmental performance of buildings, while the associated BS EN 15804 covers the environmental performance of individual products. Ideally these two standards should be read together. Other relevant standards are: PAS 2050, PAS 2080 and the ISO 14000 series.

BS EN 15978, however, is open to interpretation and does not provide detailed practical guidance on how to assess carbon emissions. This leads to a lack of reliability and comparability.

To address this issue, the RICS published a professional statement (the highest form of RICS guidance, both mandatory and regulated by the RICS, called *Whole life carbon assessment for the built environment professional statement* (RICS PS) in November 2017. The purpose of RICS PS is to bring consistency to carbon reporting. It is the recommended methodology to use for undertaking carbon assessments. It aligns with BS EN 15978 and offers practical guidance for calculating the embodied and operational emissions over a building's life as well as a reporting structure.

RICS states that the professional statement 'can be applied to all types of built assets, including buildings and infrastructure. It is suitable for the assessment of both new and existing assets as well as refurbishment, retrofit and fit-out projects'. It is available as a free download from the RICS website.

World Wildlife Fund Headquarters, Woking. Architects: Hopkins. Carbon Consultant: Sturgis Carbon Profiling. Image © Janie Airey.

This project was one of the first office projects to conduct a whole life carbon assessment.

Summary of RICS *Whole life carbon assessment for the built environment professional statement* (RICS PS)

Factors influencing the assessment

Spatial boundaries

The assessment should cover all works relating to the proposed building and its intended use, including its foundations, external works within the site and all adjacent land associated with its typical operations. A planning 'red line' can serve as the boundary if applicable.

Physical characteristics

All items within the project's cost plan/bill of quantities or equivalent information should be included. For practical reasons, the assessment should cover at least 95% of the cost of all building elements to enable cost efficiency analysis. The Elemental Standard Form of Cost Analysis, produced by RICS Building Cost Information Service (BCIS), should be referred to for definition of the building parts or elements.

Assumed building life span (reference study period)

For comparability purposes, the life expectancy of all building types is assumed to be 60 years, and 120 years for infrastructure. These periods are sufficiently long to equal or exceed the life cycles of most major replaceable systems. RICS PS explains how to assess buildings with shorter or longer life expectancies.

Life cycle assessment (LCA)

LCA is fundamental to a WLC assessment. It can be summarised as "a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to the functioning of a building throughout its life cycle" (ISO 14040: 2006). An LCA helps the architect understand, at design stage, the lifetime consequences of their design decisions. This promotes durability, resource efficiency, reuse and future adaptability, all of which contribute to life time carbon reductions. A WLC assessment should consider all emissions produced over the entire life of the building, from sourcing through construction and use to disposal (cradle to grave). It is also intrinsic to future resource efficiency and carbon reduction to consider potential reusability/recyclability of all the building elements (cradle to cradle). Therefore, all life cycle stages defined by BS EN 15978 should ideally be included in WLC studies. The benefits of reuse and recycling are relatively unpredictable and are therefore reported separately. Gauging these potential benefits is nevertheless important as it gives a carbon value to the future circular economic potential of a design.

Floor area measurement

This should be in accordance with the RICS property measurement standards (2015 onwards).

Quantities measurement

Material quantities should follow from the project cost plan/bill of quantities (BoQ), the BIM model or be estimated from drawings. These should be in accordance with the RICS property measurement standards (2015) and the BCIS Elemental Standard Form of Cost Analysis.

House in Auroville, India; Architect: Anupama Kundoo. Image © Javier Callejas.

This project used a range of intentionally low carbon ideas, including locally handmade bricks that are fired with biowaste rather than coal; masonry using lime rather than cement; roofing systems made of load bearing terracotta hollow tubes; and floor slabs made using terracotta filler elements as lost shuttering, saving 50% of structural steel. Every element was considered from the low carbon perspective to achieve the lowest carbon footprint.

Units of measurement to be reported

WLC should be reported using $kgCO_2e$ or suitable multiples thereof, e.g. tCO_2e. The reported results should be appropriate for the project type, i.e. $kgCO_2e/m^2$ NIA for most building categories, $kgCO_2e/m^3$ of internal building volume for storage and industrial units etc.

Embodied carbon data sources

The availability of accurate data on the carbon cost of materials and systems is a rapidly evolving area. Typically, Environmental Product Declarations (EPDs) are used. These are provided for an increasing number of products by the manufacturer and cover a range of data including the embodied carbon. EPDs are developed in accordance with a number of standards including BS EN 15804 and various ISO standards (see RICS PS for further detail). EPD data has been collated into databases by various providers, which generally charge for access.

Biogenic carbon

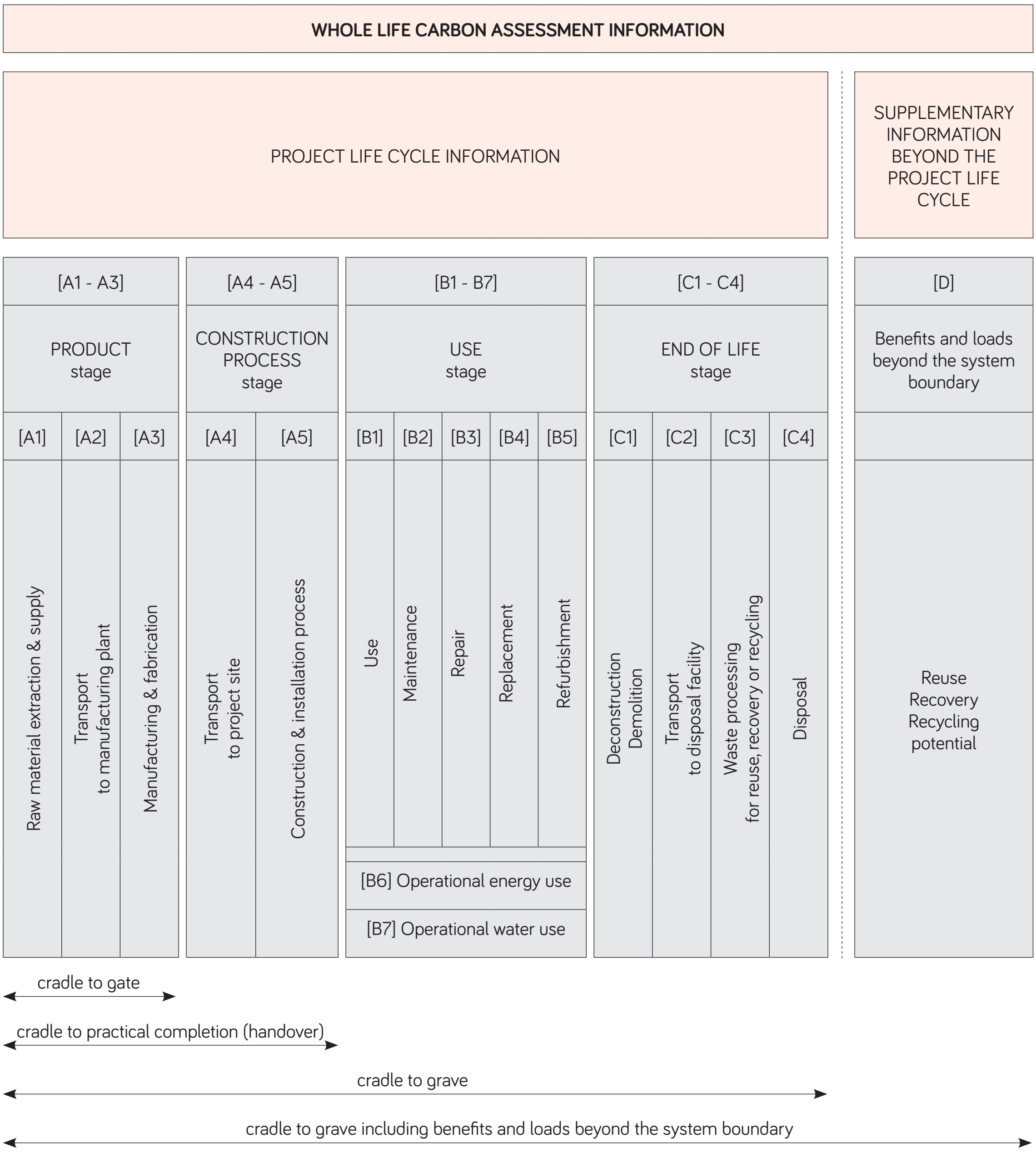
Trees absorb CO_2 from the atmosphere while they grow. This CO_2 remains locked in the timber until the end of its life. Assessing the carbon sequestered in timber structures, shuttering and other products, and how to deal with the end of life emissions, is increasingly important given the development of products such as cross laminated timber and other wood based construction products.

Grid decarbonisation

When assessing future whole life carbon performance it is important to factor in the future energy mix, which is expected to gradually decarbonise. This trend varies from country to country. For the UK, the National Grid's Future Energy Scenarios can be used to calculate future decarbonisation rates.

RICS PS structure

RICS PS follows the modular structure of BS EN 15978. The diagram below illustrates this structure, which covers both operational carbon emissions from energy and water use (modules B6 – B7) and embodied emissions (modules A1-A5, B1-B5, C1-C4, and D).



Modular reporting structure of BS EN 15978 as used in RICS PS
Module A: Product and Construction stages; Module B: In use; Module C: End of Life; Module D: potential benefits through reuse or recycling.

The Enterprise Centre, Norwich; Architects: Architype, who undertook an in house whole life carbon assessment. Image © Darren Carter.

This project shows how low carbon thinking can produce unexpected results. The thatch cladding is very low carbon, has a life span not that different to some metal cladding systems (+/-25 years), and is also low carbon to replace. Local sourcing has meant short travel distances and the social/cultural benefits of supporting a local craft industry.

Modules A1 – A3: Product stage

The product stage carbon emissions of the different construction elements should be calculated by assigning suitable embodied carbon factors derived from acceptable data sources, for example EPDs provided by the manufacturer.

Module A4: Transport emissions (factory gate to site)

This requires assessing the likely transport types and the associated emissions attributable to the products being transported from factory to site. These should be updated at PC to paint a more accurate picture.

Module A5: Construction / installation emissions

The carbon emissions from all on-site activities and plant accommodation should be covered. Appropriate allowances for site waste should be made. The site waste rates for the different materials should be estimated. Initial estimates should be replaced with evidence based site monitoring data provided by the contractor at PC.

Modules B1-B7: Use stage

This stage should capture the carbon emissions associated with any building related activities over the entire life cycle of the project from PC to demolition. The intention is to assess and highlight to the design team the likely carbon impacts of design stage decisions post PC. Taking future uncertainty into account, sensible scenarios should be developed for the maintenance, repair, replacement, refurbishment and operation of the building. An LCA is therefore an essential requirement.

Module B1: In use emissions

This covers the release of greenhouse gas from products and materials (e.g. refrigerants, paints, carpets) during the normal operation of the building.

Module B2: Maintenance emissions

The carbon emissions of all maintenance activities, including cleaning, should be taken into account, encompassing the carbon impacts from energy and water use associated with them.

Modules B3 – B4: Repair and replacement emissions

This stage involves any emissions arising from the repair and replacement of relevant building components in line with sensible scenarios developed from the LCA. These should capture all emissions associated with the supply of new products (as in A1-A5 above). It should be noted that for consistency it is assumed that repair and replacement are 'like for like'.

Module B5: Refurbishment emissions

The detailed LCA should incorporate any known refurbishment scenarios going forward. This would cover a planned future extension or change to the building.

Module B6: Operational energy use

All operational emissions from building related systems should be included as assessed at the design stage. This should cover regulated energy consumption as per Part L, including heating, cooling, ventilation, domestic hot water, lighting and auxiliary systems as projected over the life cycle of the project (excluding during maintenance, repair, replacement and refurbishment). It should also include building related systems such as lift machinery or security systems. All energy generating units such as solar thermal panels, wind turbines, gas boilers, combined heat and power (CHP) and heat pumps should be included within the calculation. Data for this section is usually provided by the services consultants and should include an estimate of unregulated energy use. Regulated energy use (as per Part L) is usually reported separately from unregulated energy use.

Module B7: Operational water use

All carbon emissions relating to operational water consumption, both supply and waste, throughout the life cycle of the building should be included.

Modules C1 –C4: End of life stage

The aim of this module is to encourage the design team to consider the perspective of the end of life, disposal or potential for reuse of the materials and systems selected. With concerns about resource depletion and the circular economy coming to the fore, it is increasingly important to understand to what extent the carbon emissions of this stage can be mitigated at the design stage. Projecting into the future is uncertain, however, for consistency the basic assumption is that processes will be the same as they are today.

Module C1: Deconstruction emissions

This module includes all emissions associated with dismantling a building that has reached the end of its life.

Modules C2: Transport emissions

This refers to transport emissions arising from removing redundant material from the building site and taking it to a disposal site.

Module C3: Waste processing emissions

Module C3 is directly linked to Module D and represents the carbon cost of processing redundant materials for repurposing, reuse or recycling. C3 represents the carbon cost to bring the materials to the 'out-of-waste' state, whereas D represents the potential benefit. For example, removing mortar from a brick would be covered under C3, whilst the benefit of the brick reuse would be shown under D.

Module C4: Disposal emissions

This includes any emissions arising from the disposal of materials to landfill or incineration.

Module D: Reuse, recovery, recycling stage

This module is described in BS EN 15978 as "supplementary information beyond the building life cycle". However, given the emerging circular economic considerations, this module is likely to become increasingly important in WLC assessments. Whereas the modules A, B, and C represent carbon costs over the life cycle of a building, Module D represents future opportunities or benefits. If a material or system has the capacity for beneficial reuse, then this carbon credit can be captured within Module D. The difficulty is that actual delivery is impossible to verify in advance. This module is intended to incentivise the design of buildings and systems that can be reused through future dismantling and subsequent reassembly. This benefit or 'offset' should be reported separately as indicated in RICS PS.

Applying RICS PS through the RIBA Stages

In order to fully integrate whole life carbon principles into the design, procurement, construction and post completion stages, project teams should be involved as early as possible. Ideally carbon assessments should be undertaken at key RIBA Stages through to practical completion. This will help optimise carbon reductions and help monitor reduction measures over the life of the project. The RICS PS methodology should be used in the context of the RIBA work stages as explained below.

RIBA
Plan of Work

RIBA Stage 0 – Strategic Definition

A client's decision to include embodied and WLC assessments within the project brief as a meaningful performance indicator is a pre-requisite. The principal reasons for undertaking WLC assessments include: full optimisation of both operational and embodied carbon reductions; future proofing of asset value by pre-empting changes in standards and legislation; marketing advantage; corporate social responsibility; added value; reduced maintenance; resource efficient design choices; and contribution to value engineering. WLC assessments also help quantify the carbon impacts of procurement choices, construction methods (e.g. off-site vs on-site), waste mitigation and disposal, and circular economic considerations.

RIBA Stage 1 – Preparation and Brief

WLC assessments form part of the sustainability aspirations within the project objectives. WLC principles can help set the strategic direction of the project, including the overall aspirations for carbon reduction and the development of carbon targets. The scope of the assessment is being decided in this stage. Ideally all modules of BS EN 15978 should be covered (i.e. A, B, C, D) and over all RIBA stages. See also: UKGBC (2017). *Embodied carbon: developing a client brief*. UKGBC, London.

RIBA Stage 2 – Concept Design

WLC thinking should be embedded within the design process from the outset. WLC analysis of design options for major built systems (structure, cladding, mechanical etc.) and the relationship with the building's proposed environmental performance should be undertaken. As an example, a WLC cost-benefit assessment of mechanical vs natural ventilation or of the use of renewables can be undertaken. WLC considerations such as climate change, future building flexibility, operational performance, intended design life and durability, materiality, deconstruction and disposal are all relevant to concept development. WLC analysis can also contribute to BREEAM credits (e.g. Mat 01) in BREEAM 2018.

RIBA Stage 3 – Developed Design

A carbon assessment should be prepared using the cost plan's material descriptions and quantities. This will be indicative but will form the baseline carbon budget. This will be a granular analysis of the project's WLC cost in as much detail as can be provided by the design team. The WLC assessment can be synchronised with any life cycle costing (as part of BREEAM Man 02). A table of detailed options and their respective impacts on the carbon budget should be prepared to enable the design team to choose low carbon and preferably cost neutral options. The relative merits, from the carbon perspective, of different construction approaches can be explored. WLC evaluations can, on occasion, contribute to planning applications through the increasing awareness of local authorities of WLC assessment.

RIBA Stage 4 – Technical Design

Low carbon choices made during Stage 3 should now be integrated into the detailed drawings, specifications and tender documentation. Suppliers can be assessed for their ability to provide relevant information with respect to fabrication methodology, factory location, energy use type, treatment of waste etc. The carbon budget should be updated and included within the tender documentation. It is important that the tender documentation ensures that the competing contractors understand the WLC requirements, the goals and process of delivering and monitoring carbon reductions during construction. This process needs to be tailored to engage with, but not burden, the supply chain.

RIBA Stage 5 – Construction

The actual carbon impacts of the construction process need to be monitored against the carbon budget and any agreements made on completion of the tender process. Communication of intent with contractors and the supply chain is essential to ensure cooperation and a positive outcome. Reporting at regular intervals, as appropriate for project size and scope, ensures continuing focus and delivery against the initial objectives, and allows for WLC impacts of variations to be brought to the team's attention. Reporting consists of interim updates to the carbon budget based on actual data from site activities, including transport movements and waste disposal.

RIBA Stage 6 – Handover and Close Out

Post PC a final review of the 'as built' information should be undertaken and a final assessment of the WLC impacts of the completed project produced. The final version of the WLC assessment should be included within the O&M manual. The final assessment should be compared to the initial carbon budgets and lessons to be learned identified.

RIBA Stage 7 – In Use

Any post-occupancy evaluation (POE) process should take account of all WLC impacts. This should include the actual performance of the building's environmental systems, together with the fabric's physical performance with respect to durability and fitness for purpose. It should include an assessment of maintenance regimes for both.

Conclusions

WLC assessments help quantify the impacts of our design choices on the environment and how to mitigate them in the most cost-effective way. They are becoming increasingly prevalent, with many clients adopting this approach. As efforts to curb climate change rise up the agenda, they are likely to become an integral part of the design process. Architects have an opportunity to take the lead if they engage early on with the methodology and thinking. It will mean architects taking greater interest in the sourcing of components and the processes involved in assembling them into buildings. It will mean thinking, at the design stages, about the future life of our buildings, and the impact on the environment of their maintenance, disposal and potential for reuse.

The Enterprise Centre, Norwich; Architects: Architype, who undertook an in house whole life carbon assessment. Image © Darren Carter.

Further reading

For practical information:

- Anderson, J. and Thornback, J. (2012). *A guide to understanding the embodied impacts of construction products.* Construction Products Association, London.
- Sturgis, S. (2017). *Targeting zero: embodied and whole life carbon explained.* RIBA Publishing, London.
- UK Green Building Council (2017). *Embodied carbon: developing a client brief.* UKGBC, London.
- Waste and Resources Action Programme (2011). *Cutting embodied carbon in construction projects.* WRAP, Banbury.

For technical information:

- Royal Institution of Chartered Surveyors (2017). *Whole life carbon assessment for the built environment.* RICS Professional Statement. RICS, London.
- Fraunhofer-Gesellschaft (2012). *EeBGuide: operational guidance for life cycle assessment studies of the energy efficient buildings initiative.* Fraunhofer, Stuttgart.
- Greater London Authority (2013). *Construction Scope 3 (embodied): greenhouse gas accounting and reporting guidance.* GLA, London, UK.
- Simonen, K. et al. (2017). *Embodied carbon benchmark study: LCA for low carbon construction.* The Carbon Leadership Forum, Department of Architecture, University of Washington, Washington, D.C.

For an overview of most relevant publications see:

- Giesekam, J. and Pomponi, F. (2017). *Briefing: embodied carbon dioxide assessment in buildings: guidance and gaps.* Proceedings of the Institution of Civil Engineers. ICE Publishing, London.

Appendix 1: Results reporting template

*Decarbonisation applicable – Report decarbonised values alongside non-decarbonised ones	Global Warming Potential GWP (TCO_2e)																			
	Product stage				Construction process stage		Use stage							End of Life (EoL) stage				TOTAL* [A] to [C] cradle to grave	TOTAL* normalised [A] to [C] cradle to grave ($kgCO_2e/m^2$ or equivalent)	Benefits and loads beyond the system boundary
	Biogenic (sequestered) carbon	[A]					[B]							[C]						
Building element category		[A1]	[A2]	[A3]	[A4]	[A5]	[B1]	[B2]*	[B3]*	[B4]*	[B5]*	[B6]	[B7]	[C1]	[C2]	[C3]	[C4]			[D]
Demolition prior to construction 0.1 Toxic/Hazardous/Contaminated Material Treatment 0.2 Major Demolition Works																				
Facilitating works 0.3 Temporary Support to Adjacent Structures 0.4 Specialist Ground Works 0.5 Temporary Diversion Works 0.6 Extraordinary Site Investigation																				
1 Substructure																				
Superstructure 2.1 Frame 2.2 Upper Floors 2.3 Roof 2.4 Stairs and Ramps																				
Superstructure 2.5 External Walls 2.6 Windows and External Doors																				
Superstructure 2.7 Internal Walls and Partitions 2.8 Internal Doors																				
3 Finishes																				
4 Fittings, furnishings and equipment																				
5 Services (MEP)																				
6 Prefabricated Buildings and Building Units																				
7 Work to Existing Building																				
8 External works																				
TOTAL																				
TOTAL - normalised ($kgCO_2e/m^2$ or equivalent unit to be stated)																				

Building-related systems
Building-related systems – regulated
Building-related systems – others
Non building-related systems

Reporting Template for undertaking a whole life carbon assessment to identify the Global Warming Potential of a project by Sturgis Carbon Profiling. The building element groups, the rows, are in accordance with the RICS Building Cost Information Service Standard Form of Cost Analysis. The columns are set out in accordance with the modules in BS EN 15978. The blue coloured cells represent the minimum 'entry level' requirement for a whole life carbon assessment. This, however, only represents a partial assessment and does not give the fullest picture. Module D, last row, quantifies the benefits of reuse, recycling and the future circular economic aspects of a design. See module B6 for information on building related systems.

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