Camden

Part 2

Embodied carbon impact of basement extensions

A technical evidence base for planning policy

December 2024 | Rev E

JENSENHUNT DESIGN Currie & Brown Etude

Overview of report structure

Sections	Description
Purpose of the study	This section provides an overview of the project, including the scope, methodology, and specific considerations for basement extensions in Camden. It introduces the concept of embodied carbon, explaining its importance in sustainable construction, and reviews the latest guidance on managing embodied and whole life carbon to align with best practices.
Context	This section covers the current policy and guidance related to basement developments, including requirements for Basement Impact Assessments and insights into emerging local plan policies. It includes a literature review to provide context and examines available resources that support best practices in basement design.
Assessment of Basement Design Parameters	This section outlines the basement design parameters reviewed and their impact upon the proportion of upfront embodied carbon in basement construction.
Assessment of Alternative Options	This section outlines the alternative approaches to counterbalance the embodied carbon of basement extensions.
Key findings	This section provides a summary of the key findings of the study and sets out a number of options that the council can consider moving forward

Contents

1 Purpose of the study 3-11

- **Embodied carbon emissions contribute to climate change** 4
- What is embodied carbon, why is it important 5
- Aim, methodology and scope of study 6
- Current guidance 9
- Factors driving significant embodied carbon in basement extensions 10

2 Context 12-19

- Current planning policy and guidance on basements 13
- Policy D6 - Basements 14
- Basement Impact Assessments (BIAs) 15
- Literature Review 16
- Resources available addressing the design of basements 19

3 Assessment of Basement Design Parameters 20-29

- Design parameters – Propped vs unpropped 21
- Design parameters – Retained height 23
- Design parameters – Bearing capacity & water table 24
- Design parameters – slab design 25
- Design parameters – cement specification 26
- Minimum and maximum embodied carbon results 28
- Limitations of the study 29

4 Assessment of Alternative Options 30-34

- Targeted Retrofit 31
- Offsetting embodied carbon 33
- Alternative extension 34

5 Key Findings 35-37

- Summary of key findings 36
- Opportunity to increase the BIA scope 37

6 Appendix

1.0

Purpose of the study

This section provides an overview of the project, including the scope, methodology, and specific considerations for basement extensions in Camden. It introduces the concept of embodied carbon, explaining its importance in sustainable construction, and reviews the latest guidance on managing embodied and whole life carbon to align with best practices.

Embodied carbon emissions contribute to climate change and should reduce in the next 10 years

Global climate emergency

There is overwhelming scientific consensus that significant climate change is happening. This is evidenced in the latest assessment of the Intergovernmental Panel on Climate Change (IPCC AR6). The IPCC Synthesis Report, published in 2023, which summarises five years of reports on global temperature rises, greenhouse gas emissions and climate impacts. To keep within the 1.5°C limit, emissions need to be reduced significantly in the next 10 years. This is therefore a decisive decade.

National commitment

The UK's national commitment is set through the Climate Change Act 2008, which was updated in 2019. It legislates that the UK must be net zero carbon by 2050 and sets a system of carbon budgets to ensure that the UK does not emit more than its allowance in the next 27 years. The concept of carbon budgets is absolutely critical to understand. Net Zero is not only about a destination: a very significant and fast decarbonisation pathway is needed.

The Climate Change Committee (CCC) UK's sixth carbon budget requires emissions to be reduced by 78% by 2035 compared to 1990 levels. The scope of the budget includes the reduction of emissions associated with products manufactured in the UK but not those used in the UK and manufactured elsewhere. By including embodied carbon (emissions from the construction process, maintenance and demolition of a building) in planning policy it will not only assist local authorities in meeting the CCC's carbon budget, but could also positively influence the decarbonisation efforts of other countries manufacturing building materials for the UK.

The CCC's Policies for the Sixth Carbon Budget suggests that to improve resource efficiency and incentivise material substitution within construction the Government should: agree a standard for the 'whole-life' carbon footprint of buildings and infrastructure with industry; introduce mandatory disclosure of whole-life carbon in buildings and infrastructure; and introduce a mandatory minimum whole-life carbon standard for both buildings and infrastructure which strengthens over time. To date, building regulations are not addressing embodied or whole life carbon.

Figure 1.1 - Net Zero: The UK's Contribution to Stopping Global Warming

(Source: CCC, 2019)

Figure 1.2 - The sixth carbon budget

(Source: CCC, 2020)

The UK's path to Net Zero

"Our recommended pathway requires a 78% reduction in UK territorial emissions between 1990 and 2035. In effect, it brings forward the UK's previous 80% target by nearly 15 years. Our pathway meets the Paris Agreement stipulation of 'highest possible ambition'."

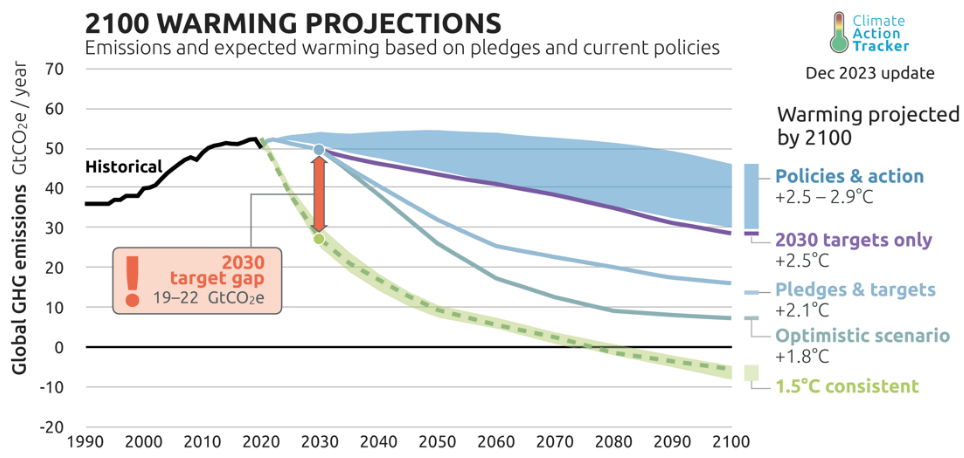


Figure 1.3 - Global warming projections, highlighting the gap between the predicted temperature rise with policies and action (2.5-2.9°C) and the temperature rise above pre-industrial levels the IPCC recommends (1.5-2.°C). A >1°C temperature rise has already been created. (Source: Climate Action Tracker, 2023)

What is embodied carbon, why is it important?

The importance of reducing embodied carbon emissions

Addressing the national carbon emission targets for the building sector has traditionally focused on reducing operational carbon emissions (associated with energy consumed in a building) through regulation and planning policy. However, as buildings become more energy efficient in operation, the operational carbon emissions of new buildings are significantly reduced. This results in embodied carbon emissions representing almost 40-70% of the whole life carbon (WLC) emissions of a new building (see Figure 1.4 and 1.5).

According to Net Zero Whole Life Carbon Roadmap technical report published by the UK Green Building Council in 2021 'Embodied carbon emissions contribute to some 40-50 million tonnes of CO_2 annually, more than emissions from aviation and shipping combined'.

Basement developments are carbon intensive

Given the number of basement extension applications coming forward in Camden over the past few years, it is safe to assume that there is a continued interest in expanding living space below ground. Addressing embodied carbon implications of this trend through planning policy is vital to meet local and national climate targets.

Bringing embodied carbon into policy

Despite the absence of building regulation in England to reduce embodied carbon, local authorities have a duty to mitigate climate change through planning policy.

An increasing number of local authorities (Greater London Authority, Westminster City Council, City of London, Bath and North-East Somerset and Bristol City Council) are incorporating embodied carbon and/or whole life carbon considerations into planning policy. To have the greatest immediate influence on the design and construction of buildings in Camden, the primary focus for this evidence base is on upfront embodied carbon of basement developments.

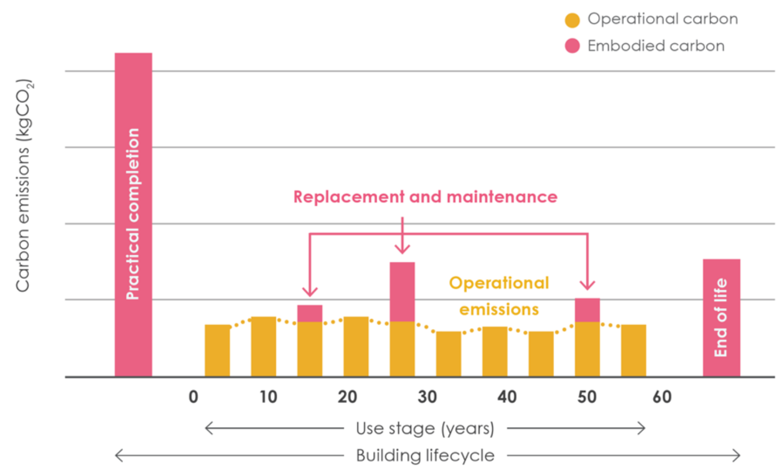


Figure 1.4 - Interaction between operational and embodied carbon throughout the lifetime of a building (Source: LETI)

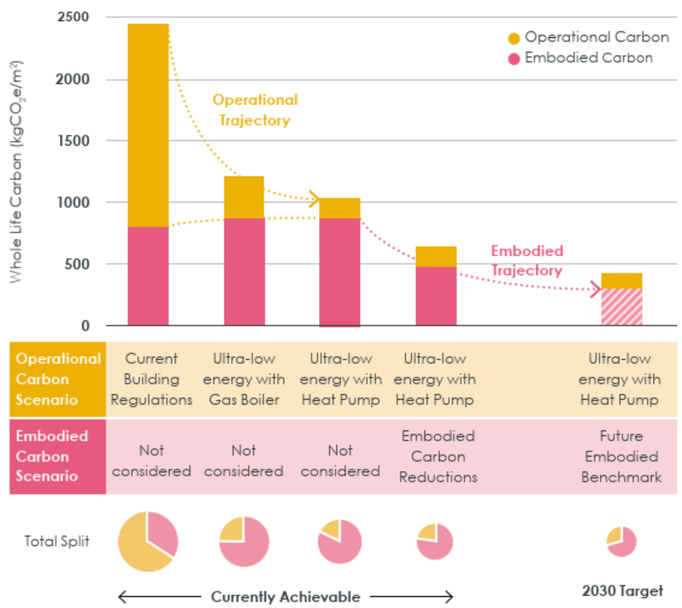


Figure 1.5 - Operational and embodied carbon trajectories. As operational emissions are reduced in new buildings, the proportion of embodied carbon emissions becomes higher. (Source: LETI)

Aim, methodology & scope of study (1/3)

Purpose of the study

The purpose of this study is to investigate how upfront embodied carbon can be reduced in basement extensions to existing residential buildings. Key findings of this study will inform the policy approach taken in the new Camden Local Plan with particular focus on reducing embodied carbon during the early design stage.

Methodology

Typical embodied carbon figures were calculated using the IStructE Structural Carbon Tool (version 2). This tool is an embodied carbon calculator commonly used by structural engineers to calculate the carbon expenditure of a structural design.

This study was based on an existing terraced house with building features typically found in London Borough of Camden (Figure 1.6).

A real basement structural scheme for the terraced house was developed based on the property's dimensions, assumed structure and loadings. This was derived using architectural floor plans for each level of the property. Where possible, the study was designed with information specific to the London Borough of Camden to ensure that any final conclusions are tailored to the area as best as possible. For example, the basement design was based on soil types typically found in the local area.

A preliminary study was conducted to determine the structural design parameters that significantly influenced the the upfront embodied carbon. Experiments were conducted on the influence of these design parameters under a range of values on the final upfront embodied carbon value.

The results of these experiments were presented in graphs and analysed in order to extract key findings presented in this report. Minimum and maximum upfront embodied carbon values were also derived.

An overview of the adopted approach is outlined in Figure 1.7.

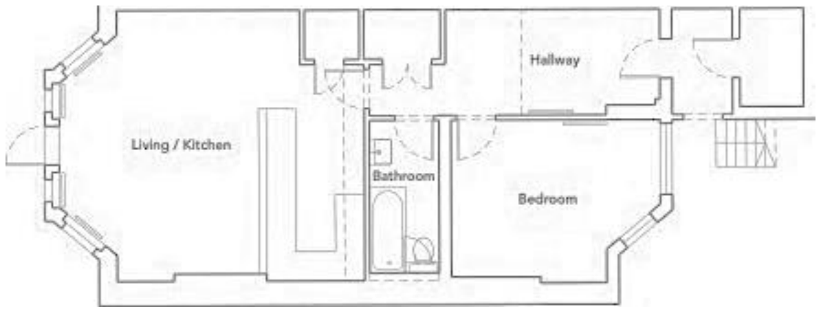


Figure 1.6: Basement floor plan of baseline model diagram

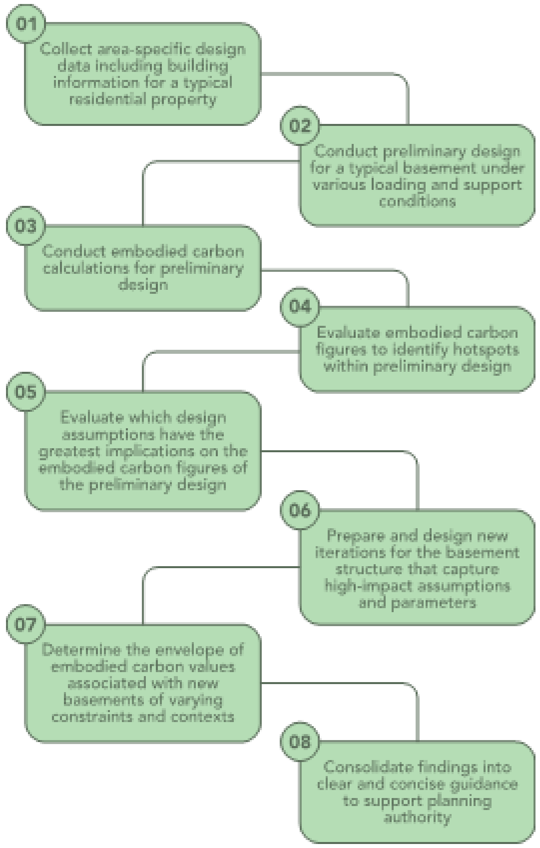


Figure 1.7: Flowchart diagram of methodology for evidence-based study

Aim, methodology & scope of study (2/3)

Scope of study

This study focusses on how developers can reduce the upfront embodied carbon of basement construction (services and finishes are therefore not considered).This study looks at domestic basements solely, as they represent the most common type of basement application in Camden. In the context of this study, a basement extension is considered to be a new space, created through excavation below the ground floor level of an existing property. The number of applications for basements in Camden can vary from year to year, between 2021 - 2023 there were 162 basement applications according to the Council's Authority Monitoring Report.

Understanding the Carbon Figures

The overall carbon expenditure of a construction project can be split into a series of stages, from the raw material supply stage to landfill. The various stages and modules are defined by BS EN 15978-1 - *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method* (2011) and shown in Figure 1.8. It is worth noting that there are other greenhouse gas emissions associated with each module e.g. methane emissions. These are captured as a carbon dioxide equivalent (kgCO_2e) value which converts other types of emissions into a carbon-equivalent value based on their relative global warming potential.

At a minimum, embodied carbon assessments for structural elements should include modules A1-A5 (upfront embodied carbon). This covers the life cycle stages up to practical completion.

A1-A5 emissions would - in theory - be released before 2050 and, therefore, should be addressed most urgently. There is also more certainty over A1-A5 emissions data compared to the other modules. Additionally, the majority of the embodied carbon of a structure would be emitted in the A1-A5 modules. For all these reasons, this study will solely focus on the embodied carbon within the A1-A5 modules (Figure 1.8).

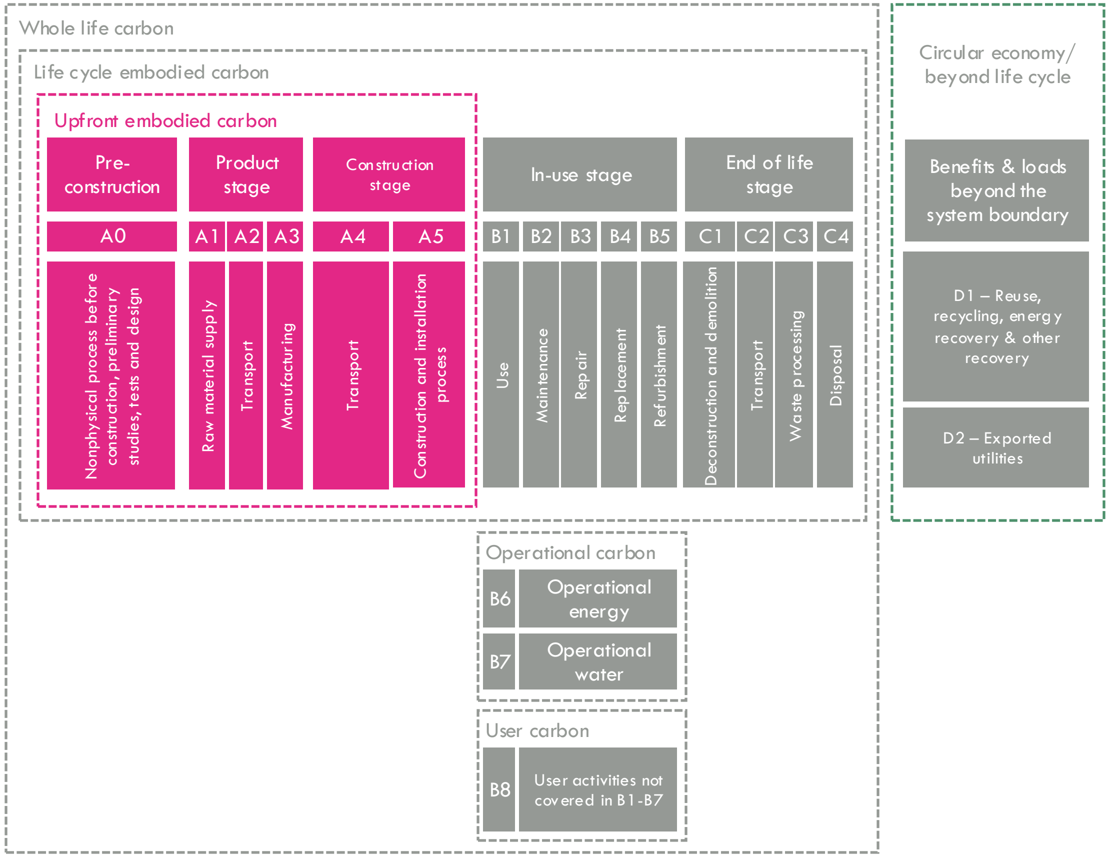


Figure 1.8 – Building assessment modules with a focus on circular economy. This version of the diagram is adapted from a combination of the diagram from the BS EN 15978-1, RICS 2023 and LETI.

Aim, methodology & scope of study (3/3)

How we calculate embodied carbon

As shown by the formulas presented in Figure 1.9, the sub-modules within the A1-A5 life cycle modules are heavily reliant on the design volume of a given material. The formulas for most sub-modules (excluding A5a) exhibit directly proportional relationships between the material volume and the embodied carbon. The formulas also indicate that embodied carbon figures are dependent on material type. However, since the majority of structural elements that are considered in the study are of concrete construction, it is reasonable to assume that the leading variable is the material volume.

This suggests that reducing the overall material volume in design is the key to achieving a reduction in the embodied carbon. This will form the basis of the study: to determine the key parameters that affect the total material volume required by design and evaluating how these parameters can be controlled, optimised or accounted for.

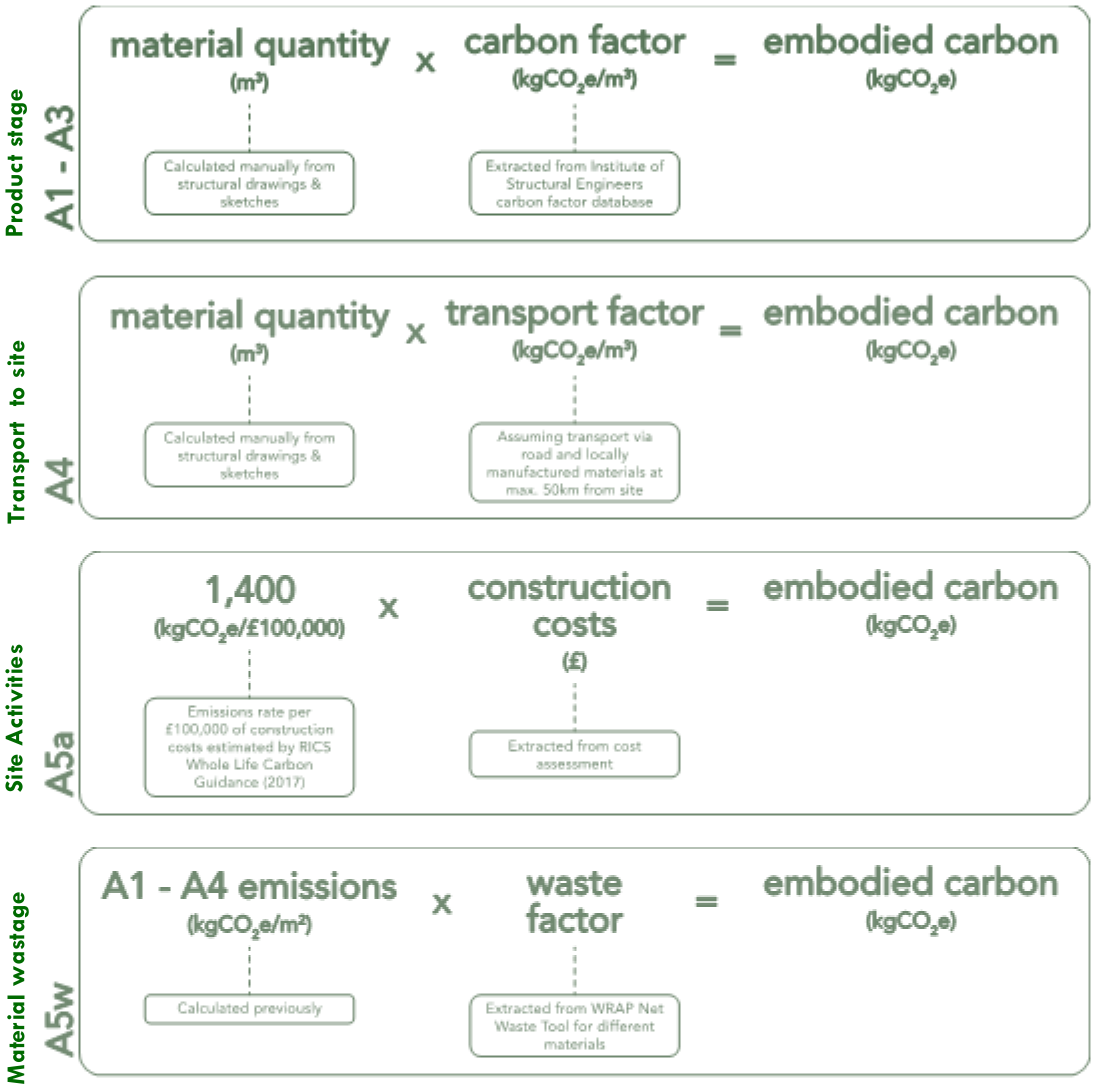


Figure 1.9 - Formulas for the calculation of life cycle modules A1-A5. Note that A5 module is split into two modules – A5a and A5w to account for the site-based emissions and material waste emissions, respectively.

Current guidance on embodied carbon and whole life carbon

RICS - Whole Life Carbon Assessment for the Built Environment

The Royal Institute of Chartered Surveyors (RICS) first published the '*Professional Statement: Whole Life Carbon (WLC) assessment for the built environment*' in 2017. It is the industry standard methodology for calculating embodied carbon and thus is used as a methodology when calculating the embodied carbon of basements. It provides supporting guidance in line with BS EN 15978 principles. The document outlines the minimum scope required for a WLC assessment, including demolition, facilitating works, substructure, superstructure (structural element, building envelope, internal elements), finishes, fittings, furnishing and equipment (FF&E), services (MEP) and external works within the building's boundary. RICS accounts for sequestered carbon in materials separately but does not account for biogenic carbon losses from the existing site (existing plants, habitats, etc.). A second edition of RICS Professional Statement was published in 2023 and is due to take effect in July 2024. Key changes include:

- The separate reporting of buildings within a site.
- The introduction of new life-cycle stages, some of which are mandatory to report (e.g. A5.1, demolition).
- The alignment of carbon data with the cost plan of the projects.
- The separate reporting of carbon offsets and biogenic carbon.
- The rating of quality of data for carbon emissions.

Other useful guidance and targets

Additional useful embodied carbon information is available from the Royal Institute of British Architects (RIBA), Low Energy Transformation Initiative (LETI), Chartered Institution of Building Services Engineers (CIBSE), Building Research Establishment's BREEAM, the UK Green Building Council (UKGBC), the Institution of Structural Engineers (IStructE) , the Centre for Windows and Cladding Technology (CWCT) , the Concrete Centre, industry proposed Building regulations Part Z, Buildings as Material Banks (BAMB), and the UK Net Zero Carbon Building Standard (NZCBS) - currently under development.

Professional standard for assessment:

Figure 1.10 - RICS 2017 (left) and 2023 (right) professional statements: Whole Life Carbon assessment for the built environment.

Industry guidance and targets:

Figure 1.11 - RIBA 2030 climate challenge

Figure 1.12 - LETI embodied carbon primer

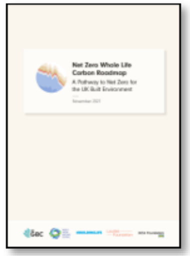


Figure 1.13 - UKGBC – Net zero whole life carbon roadmap

Figure 1.14 - UK Net Zero Carbon Building Standard

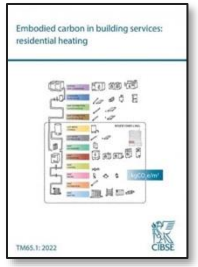


Figure 1.15 - TM 65 – Embodied carbon in building services

Other useful guidance:

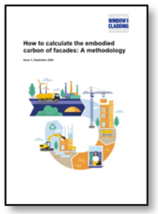


Figure 1.16 - CWCT– How to calculate embodied carbon of facades

Figure 1.17 - The concrete centre– Sustainable concrete

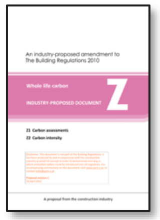


Figure 1.18 - Part Z proposed amendment to building regulations

Figure 1.19 - BAMB –Material passports

Factors driving significant embodied carbon in basement extensions

Can basements be sustainable?

Often different opinions arise when justifying the construction of a new basement within an existing residential property. Some argue that including basements can promote sustainable homes with high adaptability of space and flexibility of structure. This argument can be valid where there are isolated flats within each floor of a terraced building as basements can contribute significantly to occupancy-land efficiency – accommodating more occupants without expanding beyond the existing land area.

Defining sustainability in terms of embodied carbon

Nonetheless, when assessing the sustainability of basements, embodied carbon has increasingly become the focus of the conversation, due to their high usage of concrete and its associated embodied carbon expenditure.

In above-ground aspects of a typical extension, timber and steel can be used as very good alternatives to cementitious materials in elements such as the floor and wall structures. Lower embodied carbon values are typically much easier to achieve with these materials as demonstrated in the figures shown in Table 1.

Installing a basement includes the construction of a new basement floor and walls, shown in Figure 1.20. The most common and suitable material is reinforced concrete as it has inherent properties including water resistance, durability, strength and cost efficiency. When comparing against these properties, neither timber nor steel can be deemed feasible alternatives to reinforced concrete.

Other sources of embodied carbon

It is reasonable to only consider the primary structural elements to obtain an insight into the overall embodied carbon expenditure of basements, as these present the higher emissions; however other elements within the basement construction, such as finishes, fittings and equipment (FF&E) can be expected to display significant embodied carbon values.

Structural material	Embodied carbon per unit mass ($kgCO_2e/kg$)
Concrete In-situ C32/40	0.120
Steel UK rolled section	1.740 *
Timber Global softwood	0.263 *

** While steel and timber exhibit greater carbon factors, they have greater strength-to-weight ratios meaning they are typically used in smaller mass quantities.*

Table 1.1 - Embodied carbon factors for A1-A3 modules for common structural materials used in residential builds. (Source: Inventory of Carbon & Energy database)

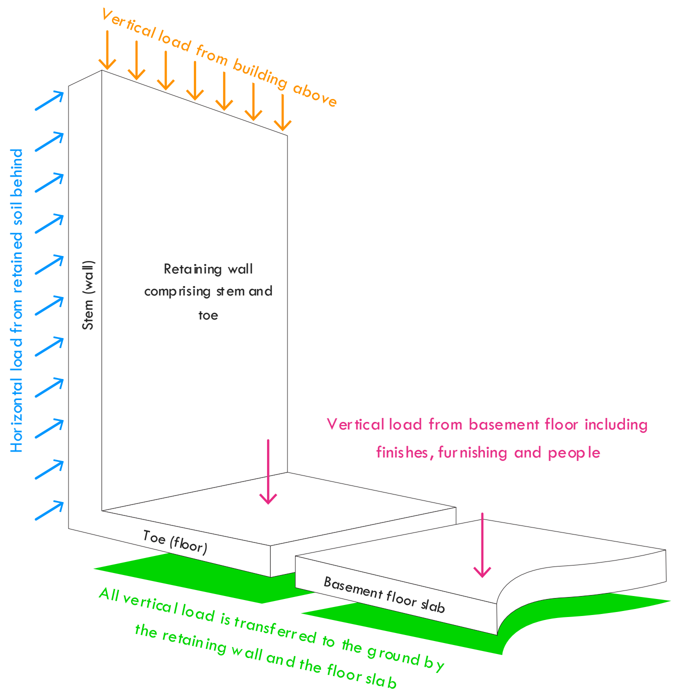


Figure 1.20 - Schematic diagram showing structural elements associated with typical domestic basements, namely the basement floor slab and the retaining wall. Typical loading subjected on structural elements also shown.

Factors driving significant embodied carbon in basement extensions

Typical basement wall structures

For domestic basements and particularly, for basements installed to an existing home, cast in-situ reinforced concrete is the most common construction method as shown in Figure 1.21. This is mainly due to its ease of placement under existing structures as well as its cost benefits. Other forms of concrete usage can be found, including alternatives like concrete piles and insulating concrete formwork (ICF).

Typical basement floor structures

Basement floor slabs are most commonly cast with in-situ reinforced concrete. Aside from strength and durability benefits, the choice to use in-situ concrete is also driven by the retaining wall construction as many contractors prefer to work with the same material when constructing a basement. Additionally, the basement floor slab is either bearing onto the ground below or in proximity to it; therefore, the floor slab is required to be durable and resistant to detrimental soil behaviour i.e. heave or swelling for which concrete performs very well.

Early-stage control of embodied carbon

There is an incentive to account and reduce the high embodied carbon expenditure of basements through design. It is well-established that the potential reductions are greatest at the beginning of the design and planning phase.

Complexity of structural basement design

The first step in determining realistic targets and guidance is understanding the embodied carbon associated with a new basement. The structural design of a basement is notoriously complex due to the number of governing design parameters and the reliance on geotechnical information.

The latter remains a prominent unknown with a considerable level of uncertainty during the design stage. Additionally, complex relationships exist between different design parameters. Indeed, a design parameter may be favourable by increasing the strength of the retaining wall while simultaneously causing an unfavourable effect on the overturning of the same wall. For example, increasing wall thickness can help to reduce the risk of overturning while increasing the risk of bearing failure. To overcome this, engineers are often required to be conservative in their design which, in turn, leads to over-designed basement structures which leads to higher embodied carbon.

Key differences between above-ground extensions and basements

Basement extensions generally have a significantly higher embodied carbon footprint compared to above-ground extensions due to the materials and construction methods required. Basement construction involves extensive excavation, adding to carbon emissions through fuel use and soil removal. The Life cycle carbon analysis of extensions and subterranean developments report by Eight Associates indicate that single-storey basements can be around 55% more carbon-intensive than comparable above-ground extensions. Although basements may offer potential long-term operational carbon savings due to natural insulation, this benefit takes years to offset the initial embodied carbon.

Figure 1.21 – Example of cast in-situ reinforced concrete walls and floor (© Net lawman)

2.0

Context

This section covers the current policy and guidance related to basement developments, including requirements for Basement Impact Assessments and insights into emerging local plan policies. It includes a literature review to provide context and examines available resources that support best practices in basement design.

Current planning policy and guidance on basements

London Plan (2021)

Policy D10 of the London Plan requires boroughs to establish policies to address the negative impacts of basements. However, it focuses on 'large-scale' basements.

Camden Local Plan (2017)

Policy A5 seeks to address the risks of ground instability and flooding as well as to minimise construction impacts in order to protect both the environment and adjoining neighbouring properties.

It restricts the location, size and scale of a new basement and requires the applicant to demonstrate that its impact will be acceptable through the submission of a Basement Impact Assessment (BIA).

Camden Planning Guidance on Basements (2021)

Camden Council has prepared the Camden Planning Guidance (CPG) on Basements to support the policies in the Camden Local Plan 2017. Its objective is that new basements do not cause harm to neighbouring properties; the structural, ground, or water conditions of the area; the character and amenity of the area; and the architectural character and heritage significance of the building and area.

It requires applicants to describe within their Design and Access Statement how the development has considered materials, resources and energy but does not have more specific requirements, which is partly why this evidence base has been commissioned.

Other London boroughs

Several other London boroughs have developed policies and guidance on basements, including: the Royal Borough of Kensington and Chelsea, the London Borough of Islington, the London Borough of Richmond upon Thames and Westminster City Council.

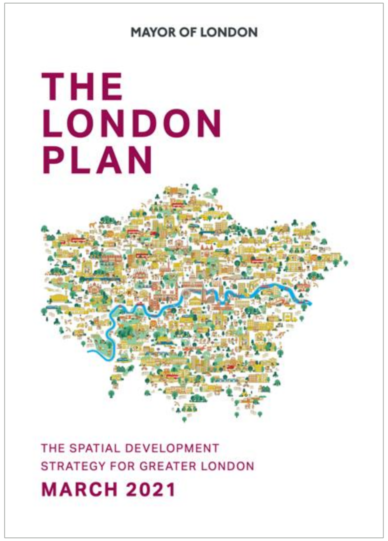


Figure 2.1 – London Plan (2021)

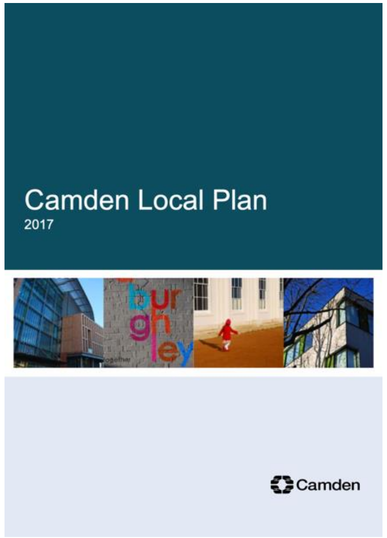


Figure 2.2 – Camden Local Plan (2017)

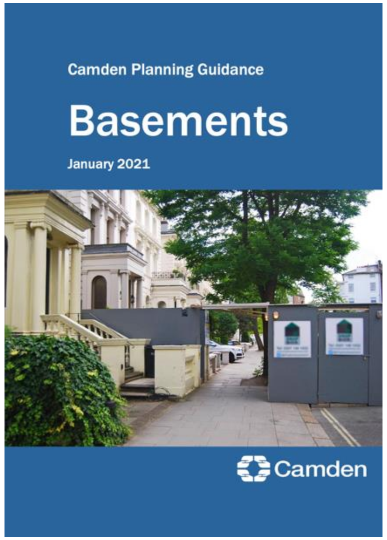


Figure 2.3 – Camden Planning Guidance on Basements (2021)

Figure 2.4 – Draft New Camden Local Plan (2024)

Draft New Camden Local Plan (2024)

Camden Council has published its draft new Local Plan for consultation and engagement (Regulation 18 stage).

Policy D6 is proposed on Basements.

The draft local plan 2024 helps to minimise carbon emissions

Policy D6 already includes several requirements which will help to minimise carbon. In particular:

1. The requirements that basement developments should not comprise of more than one storey (C.i.) and that they should not exceed the footprint of the 'host building in area (C.iii) will minimise the scale of the basement and therefore its **embodied carbon.**
2. The requirement that applicants should demonstrate that proposals for basements have sought to offset the carbon impact of the construction of the basement by reducing energy demand across the whole of the building (E.iii) could have the combined effect of incentivising applicants to reduce both **embodied carbon** and **operational carbon**.

Policy D6 – Basements

A. The Council will only permit basement development where it is demonstrated to its satisfaction that the proposal would not cause harm to:
   i. neighbouring properties;
   ii. the structural, ground, or water conditions of the area;
   iii. the character and amenity of the area;
   iv. the architectural character of the building; and
   v. the significance of heritage assets.

B. In determining proposals for basements and other underground development, the Council will require an assessment of the scheme's impact on drainage, flooding, groundwater conditions and structural stability in the form of a Basement Impact Assessment and where appropriate, a Basement Construction Plan.

C. The siting, location, scale and design of basements must have minimal impact on, and be subordinate to, the host building and property. Basement development should:
   i. not comprise of more than one storey;
   ii. not be built under an existing basement;
   iii. not exceed the footprint of the host building in area, except for works to create a lightwell or access to the basement;
   iv. be set back from neighbouring property boundaries;
   v. avoid the loss of garden space or trees of townscape or amenity value, i.e. from construction work or due to the creation of a new access or lightwell.

D. Exemptions to C(i) to C(v) above may be made on large comprehensively planned sites.

E. The Council will require applicants to demonstrate that proposals for basements:
   i. do not harm neighbouring properties, including requiring the provision of a Basement Impact Assessment which shows that the scheme poses a risk of damage to neighbouring properties no higher than Burland Scale 1 'very slight';
   ii. avoid adversely affecting drainage and run-off or causing other damage to the water environment;
   iii. have sought to offset the carbon impact of the construction of the basement by reducing energy demand across the whole of the building;
   iv. avoid cumulative impacts;
   v. do not harm the amenity of neighbours;
   vi. do not harm the appearance or setting of the property or the established character of the surrounding area;
   vii. protect important archaeological remains; and
   viii. ensure impacts on any green/garden space or trees are minimised and where residual impacts do arise that this is addressed through appropriate restoration and replacement.

F. The Council will not permit basement schemes involving self-contained flats or bedrooms, bathrooms or kitchens in basements in flood risk areas.

G. We will generally require a Construction Management Plan for basement developments.

H. Given the complex nature of basement development, the Council expects developers to offer security for expenses for basement development to adjoining neighbours.

Figure 2.4 – Policy D6 on Basements from the Draft New Camden Local Plan (2024)

Current guidance on Basement Impact Assessments (BIAs)

A clear and thorough process

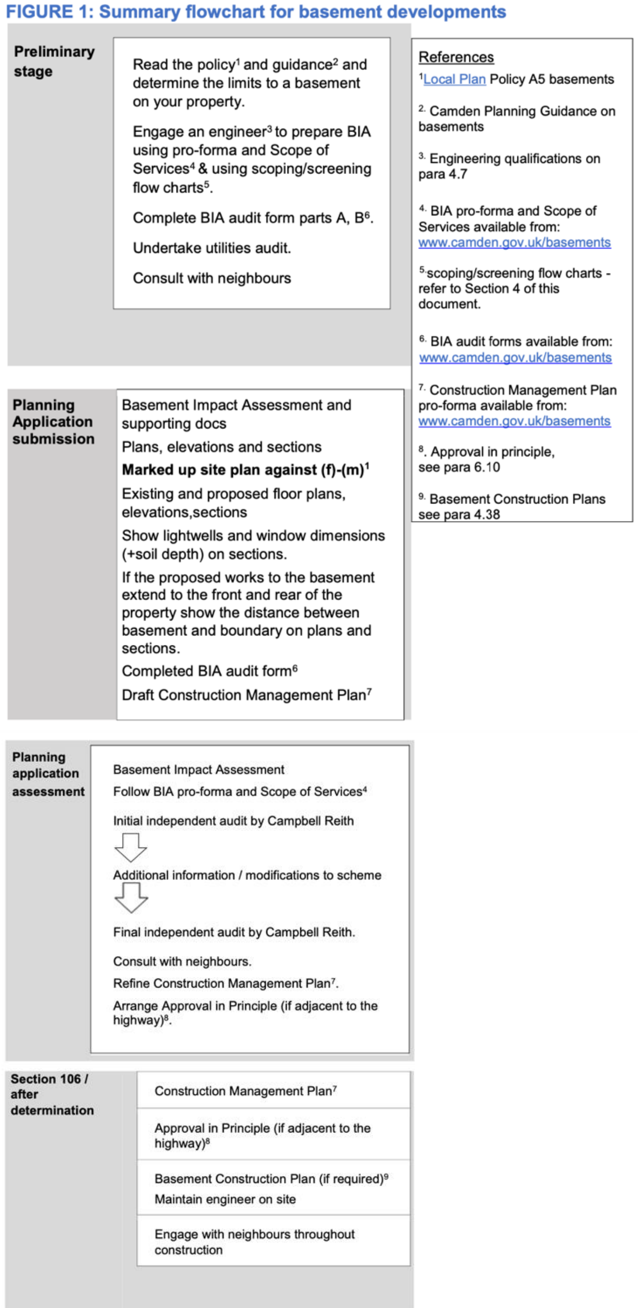
The basement impact appraisal process was set up in 2010 and focuses on the impact on ground water flow, flooding and neighbouring properties. There are five stages to be completed by the applicant, with the first three being mandatory: (1) Screening with 25 questions (2) Scoping (3) Investigation (4) Impact assessment (5) Mitigation. The BIA is then issued by the applicant to Camden who will undertake a two-stage audit of it (through their appointed specialists, currently Campbell Reith).

The quality of information underpinning the BIA is key. Physical measurements are usually needed, and Camden Council generally requires a structural engineer to be appointed to increase the robustness of the information submitted.

Environmental issues covered by the BIA process

Other than issues associated with the stability of and potential damage to neighbouring properties, the current environmental issues covered by the BIA include mainly flooding and the water environment (drainage, run-off, ground permeability) as well as biodiversity.

Figure 2.5 – Basement Impact Assessment (BIA) proforma (above) and summary flow chart for basement developments (right).



Literature review | Existing evidence bases (1/3)

Research on basement's embodied carbon remains scarce

Basements, by nature, involve extensive excavation, use of high-carbon materials like concrete, and complex construction processes, all of which contribute to their embodied carbon footprint. Despite these factors, there is a scarcity of comprehensive studies and data focused on quantifying and analysing the embodied carbon of basement construction. This gap in the literature presents challenges for policymakers, architects, and engineers striving to develop and implement more sustainable building practices that encompass all aspects of a building's lifecycle. Hence the significance of this evidence base for both Camden Council as well as the wider industry.

Embodied carbon evidence base key takeaways

Westminster City Council commissioned WSP to develop an evidence base focusing on the embodied carbon in various building types, including basements. The report primarily addresses new-build constructions however some of the key takeaways also apply to basements extensions in existing buildings.

The report highlights a key challenge in current carbon assessment methodologies: they do not distinguish between buildings with and without basements. This lack of differentiation can penalize developments with basements, making it hard to meet stringent embodied carbon targets set by frameworks like LETI and RIBA.

This finding suggests a need for revised policies that either discourage basement construction or provide clear guidelines and offsets for projects that necessitate basements. Additionally, it emphasizes the importance of considering basements' carbon impact early and explore alternative solutions that could reduce the overall carbon footprint of a building, such as an above ground extension or reutilising existing space.

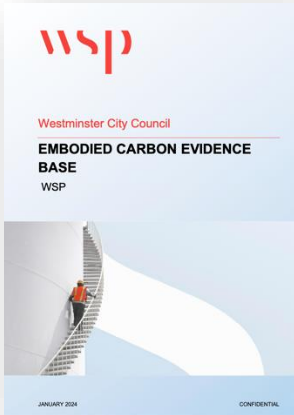


Figure 2.6 - Embodied Carbon Evidence Base, WSP 2024

Key takeaways

- Including basements developments within both new and existing buildings significantly increases embodied carbon. For example, the addition of a single storey basement resulted in a 24% increase in carbon for mixed-use and office buildings and a 17% increase for (new-build) residential buildings. Even when normalizing the embodied carbon values across the Gross Internal Area (GIA), the increase is significant and might even be higher when considering the carbon associated with enabling works or groundworks.
- The report suggests reducing grid spacing of structural frames, (to reduce the thickness of framing elements), using low carbon concrete, incorporating CLT (cross-laminated timber), and utilizing recycled materials to minimize embodied carbon.
- Policies should explore providing other financial incentives to applicants to equally boost the total lettable floor area, such as allowing additional above-ground floors.
- Establish clear, ambitious embodied carbon targets that consider the significant impact of basements and encourage design strategies that avoid their inclusion where possible. All typologies to adopt Net Zero Carbon Buildings Standard (NZCBS) limits

Literature review | Existing evidence bases (2/3)

Evidence Base for Basements and Policy CE1: Climate Change

Eight Associates were commissioned by Royal Borough of Kensington and Chelsea to provide an evidence base addressing the need for updated policies regarding the development of basements.

The primary aim of the report was to update the Core Strategy Policy CE1 by replacing the outdated EcoHomes assessment with the BREEAM Domestic Refurbishment 2014 method.

Carbon Emissions

The evidence base indicates that basements have significant embodied carbon compared to above-ground masonry extensions. This is primarily due to the materials and construction methods required for subterranean development.

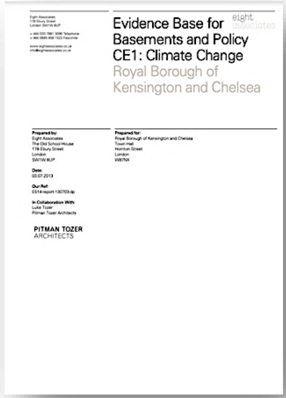
To mitigate this, the evidence proposed that policy CE1 should offset basement emissions through environmental improvements to the original building, emphasizing fabric upgrades i.e. internal wall insulation and efficient service systems to meet the minimum Post Refurbishment Energy Efficiency Rating (EER).

The EER is equivalent to the SAP ratings from SAP energy calculations.

Implementation and historic building considerations

The report outlines a detailed implementation strategy, including pre-application guidance and mandatory BREEAM assessments at various stages of development.

Special considerations are given to historic and listed buildings, where the focus is on service improvements rather than structural changes to preserve historical integrity.


Evidence Base for Basements and Policy CE1: Climate Change
Royal Borough of Kensington and Chelsea

PITMAN TOZER ARCHITECTS

Figure 2.7 - Evidence Base for Basements and Policy CE1: Climate Change, Eight Associates 2013

Key takeaways

- The study found that basements are much more carbon intensive than above ground extensions.
- The report recommends the use BREEAM Domestic Refurbishment as the policy tool for assessing and mitigating the carbon impact of basements.
- The report also recommends that the additional embodied carbon emissions resulting from basement constructions should be counterbalanced through energy efficiency measures to the original building.
- The recommended policy favours operational carbon targets based on EER ratings i.e. SAP energy calculations.
- BREEAM Domestic Refurbishment does not require an embodied carbon assessment, however the Mat 01 credits for ‘Environmental Impact Materials’ assesses building materials based on Green Guide ratings associated with Environmental Product Declarations (EPD).
- There are no explicit requirements or methodology set out to undertake an embodied carbon assessment of a proposed basement pre-construction.

BREEAM Domestic Refurbishment

For refurbishment and fit-out projects, credits are awarded for completing life cycle assessments (LCA) during the early/concept and technical design stages, with mandatory carbon emissions reporting in $kgCO_2eq/m^2$. A standardised reporting template is used, and credits are given based on performance against embodied carbon benchmarks. The LCA must cover all relevant building elements, accounting for at least 95% of the allocated capital cost for each category. Although this method provides a standardised framework to measure and reduce embodied carbon the complexity of the assessment and the need to account for a high percentage of capital costs across building elements may be impractical for smaller projects.

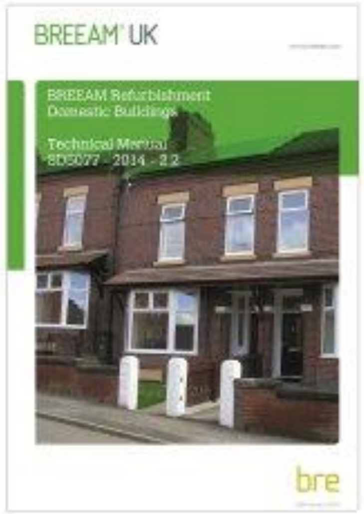


Figure 2.8 – BREEAM Refurbishment Domestic Buildings 2014 Technical Manual

Resources available addressing the design of basements

Existing literature and guidance

There are tools and guidance within industry commonly used to assess the impact of the embodied carbon of structural components more generally. However, there is very little design guidance within the realm of structural engineering specific to reducing the embodied carbon of a basement during the early design stages.

Current common practice of structural design

Despite access to these resources, embodied carbon of basements is not currently integrated into common structural design practice. This, along with the complexity and uncertainty of retaining wall design, suggests that carbon-conscious basement design is not the norm within the industry.

This is also reflective of the preference within the construction industry to maintain traditional design practices instead of challenging common procedures for leaner options, particularly in the case of small-scale residential builds.

Overcoming the lack of information

This study was conducted to better understand the relationship between various design parameters and the volume of concrete required, which is proportional to the embodied carbon.

The objective is for the Council to use the findings of this study to inform local policy and guidance. The study was conducted with information specific to the London Borough of Camden to ensure that the findings are tailored to the area as best as possible.

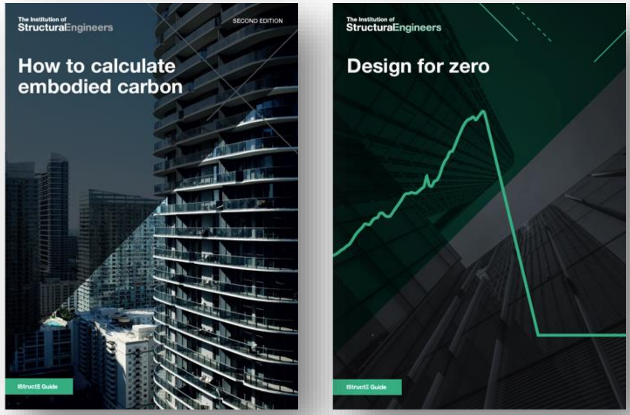


Figure 2.9 - IStructE – How to calculate embodied carbon, 2022 & Design for Zero, 2021.

3.0

Assessment of Basement Design Parameters

This section outlines the basement design parameters reviewed and their impact upon the proportion of upfront embodied carbon in basement construction.

Evaluation of structural design parameters | Propped vs unpropped (1/2)

As part of the study several basement design parameters have been reviewed to assess their impact on the embodied carbon of basement construction. The results of this assessment are set out below.

Governing design parameters

The results of a preliminary study and sensitivity analyses revealed the following design parameters as the most impactful in terms of concrete volume and, in turn, embodied carbon of the basement structure:

1. Propped vs. unpropped
2. Retained height
3. Bearing capacity of base soil & depth of groundwater table
4. Basement slab design
5. Cement specification

The results from the study are presented graphically within Appendix A. These graphs were analysed further to draw conclusions presented in this report.

Propped vs. unpropped

Propped retaining walls are defined by an additional propping support at the top of the retaining wall stem provided by a solid concrete ground floor structure. On the contrary, unpropped retaining walls are not supported at the stem level and, thus, do not rely on a concrete ground floor construction (Figure 3.1 - *right*). Unpropped basements are usually the default design option due to the relative ease of construction. However, for deeper basements, propped retaining walls are required as the additional support increases the capacity of the retaining wall.

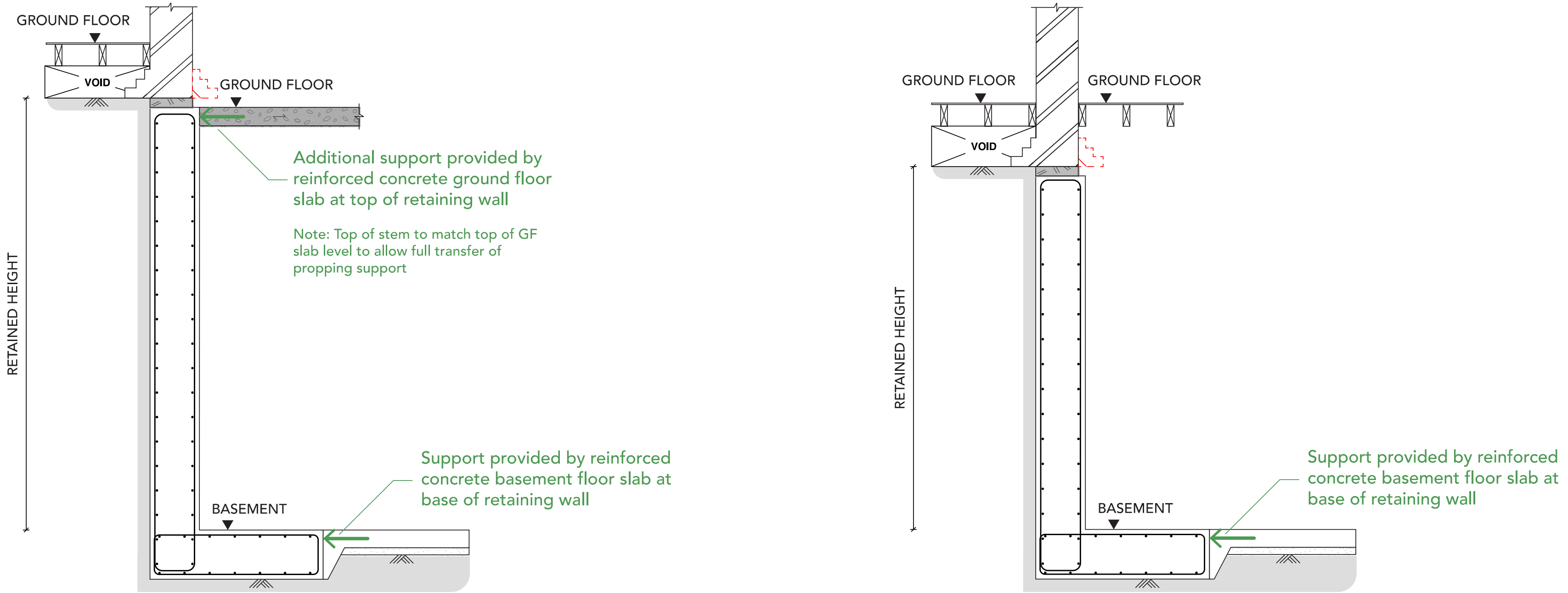


Figure 3.1 - Schematic diagrams showing support conditions of propped (left) and unpropped (right) retaining walls.

Evaluation of structural design parameters | Propped vs unpropped (2/2)

Due to the extra support seen in propped basements, retaining walls are typically thinner compared to unpropped designs, particularly at greater basement depths.

A propped basement system is usually associated with thinner retaining walls and, in turn, lower embodied carbon due to the additional support provided by the ground floor slab. However, the embodied carbon contribution of this reinforced concrete ground floor slab is often overlooked. The findings of the study demonstrated that, in some cases, an unpropped basement can be less carbon-intensive than its propped counterpart. Indeed, savings of as much as 30% could be seen with an unpropped system versus a propped system for the same bearing capacity and retained height. The only instance where the propped condition proved to exhibit carbon savings is where the retained height is 5m and the bearing capacity is 150kN/m^2. This suggests that the propped solution should be implemented only in cases where a deep basement is required in the presence of weak soil. The results also showed that implementing propped retaining walls would allow basements to be built for a range of depths even with poor soil conditions.

Policy A5 of Camden's Local Plan states that new basement proposals must demonstrate a risk of causing damage to neighbouring properties not exceeded Category 1 – Very Slight on the Burland Scale. Both propped and unpropped basements can be designed to achieve this risk category. Therefore, in the majority of cases, the need to satisfy this category should not be a driving factor in choosing between propped and unpropped basements.

Key findings & considerations:

- Propped basement proposals should be challenged where reasonable bearing capacity of the soil is expected i.e. 150-200 kN/m^2 and the retained height does not exceed 3m.
- Propped basement proposals should not be prohibited in their entirety as cases may arise where they are the only feasible option to achieve a basement.
- Challenge a "one size fits all" approach to entirely propped/unpropped basements. Encourage applicants to consider a mixture of propped and unpropped retaining walls in order to rationalise the volume of concrete required.
- Designers should explore the use of profiled concrete ground floor slabs i.e. Comflor which utilise less concrete but are still able to provide a propping support.

Evaluation of structural design parameters | Retained Height

Retained height

The retained height is the depth of soil that a retaining wall must support along its external face. It is measured from the top of soil level to the bottom of the basement retaining wall. An example of the retained height is illustrated in Figure 3.2.

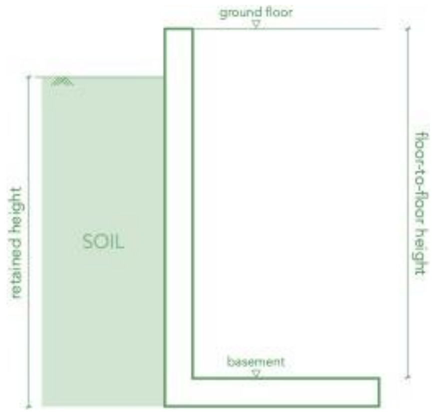


Figure 3.2 – Schematic diagram showing example of retained height and floor-to-floor heights of a typical retaining wall

The retained height of a basement is predominately governed by clear height requirements and architectural design. In cases of weak soil conditions, designers may choose to also increased basement depth to reach good soil as an alternative to deeper basements.

The retained height was found to be the most influential design parameter in terms of the concrete design volume and, in turn, the total embodied carbon. The general trend saw that greater retained heights required thicker retaining walls to support the extra horizontal load from the soil which resulted in greater embodied carbon values. For example, for the propped retaining wall with 150 kN/m^2 bearing capacity and a ground-bearing slab, the embodied carbon increased by 73 kgCO_2e/m^2 when the retained height increased from 2m to 4m.

The unpropped retaining walls exhibited a less linear relationship between the retained height and the embodied carbon. Increases in the retained height saw larger jumps in the embodied carbon.

Interestingly, for bearing capacities of 150-200 kN/m^2, the optimum retained height for unpropped basements was found to be approximately 3 metres. This is exhibited in Figures 5.A.2 & 5.A.5, where retained heights of 3 metres demonstrated the lowest embodied carbon values. Embodied carbon values increase as the retained height deviates from 3m, towards both 1m and 5m retained heights.

Key findings & considerations:

- Require proposed basement depths to be justified as part of the planning application regardless of whether the retaining walls are propped or unpropped
- For unpropped cases in particular, basement depths that require retained heights exceeding 3m should require a higher level of justification that includes the measures taken to ensure the basement depth is as minimised as possible.
- Where retained heights are less than 3m, it may be useful to request applicants/structural engineers to explore the impact on concrete volume if increasing the basement depth to a 3m retained height. Alternatively, it may be useful for structural engineers to demonstrate the impact of increasing the retained height on the volume of concrete required by design.

Evaluation of structural design parameters | Bearing capacity & water table

Bearing capacity & depth of groundwater table

Bearing capacity is governed by the existing soil profile at the basement floor level. In the context of the London Borough of Camden, the load-bearing soil stratum at this depth is typically comprises of London Clay with a bearing capacity range of 100 – 250 kN/m^2 according to the Code of *practice for foundations* - BS8004:1986 & *Camden geological, hydrogeological and hydrological study - Guidance for subterranean development* by Arup (November 2010)

For both propped and unpropped basements, a variation in the bearing capacity demonstrated little to no impact on the embodied carbon. This is because in some cases the failure of the retaining wall was not governed by the strength of the soil but instead by the geometries of the retaining wall. There may be temptation to state that geotechnical investigations are not necessary for the design of a basement and its planning application. However, the study utilised a very idealistic soil profile where the effects of tree roots, soft spots, movement risks & irregularities were not modelled. Therefore, the results should be viewed with a degree of caution as, in reality, these effects can affect basement design considerably.

Water table depth can vary significantly across Camden and between neighbouring properties, particularly with the presence of existing basements in neighbouring properties. Water table depth can also vary temporary during the construction of a new basement.

Water table (groundwater) within the retained height of soil was investigated as part of the study and it was found that, for the unpropped condition, a higher water table required a greater volume of concrete. As the water table travelled from 4m below ground level to ground level, the embodied carbon increased by 128 kgCO_2e/m^2.

The groundwater depth had no influence on the retaining wall design under a propped condition.

Key findings & considerations:

- The current Basement Impact Assessment process requires geotechnical investigations to be undertaken prior to the submission of a planning application.
- Geotechnical investigations should use geotechnical desktop studies to determine and address uncertainties within the soil.
- In the absence of complete geotechnical investigations, permit the use of a minimum 100 kN/m^2 bearing capacity at the planning design stage.
- Require that geotechnical investigations are conducted at a later stage in the project (but prior to the construction stage) to capture a more complete picture of the existing soil profile and confirm the bearing capacity of the soil.
- Include groundwater monitoring as part of the geotechnical investigations.

Evaluation of structural design parameters | Slab Design

Basement slab design

Basement floor slabs are most commonly cast with in-situ reinforced concrete as either a suspended slab or a ground-bearing slab. As the name suggest, the latter option relies on the ground for support and, thus, requires soil of sufficient strength. Where the existing soil profile is deemed too weak to support the floor or where significant ground movement is expected, a suspended slab is often specified. Since suspended slabs are expected to support themselves without aid from the ground, they are usually thicker than ground-bearing slabs.

The basement slab design (suspended slab or ground-bearing slab) exhibited very little influence on the embodied carbon. As previously mentioned, these were designed based on idealistic soil profiles. Therefore, there may be cases where much thicker basement slabs may be required.

The embodied carbon of the basement slabs contributed a considerable proportion (approx. 30%) of the total embodied carbon in cases where the retained height did not exceed 1m i.e. for cellars or deepening of basements with existing neighbouring basements.

Key findings & considerations:

- Where the retained height is greater than 1m, more focus should be made on the embodied carbon associated with the retaining walls.
- Where the retained height is 1m or less (i.e. when the basement is being deepened slightly), both the embodied carbon of the retaining walls and the slab should be considered. For ease of the applicants, it is acceptable for an allowance to be applied to the embodied carbon figure of the retaining walls to account for the embodied carbon of the slab. The findings of the study suggests that a factor of 30% is acceptable.

Evaluation of structural design parameters | Cement Specification (1/2)

Cement specification

The concrete strength class (C30/37, C32/40, etc.) specified by the engineer is often a key contributor to the final embodied carbon number. Table 3.1 shows that as the strength of concrete increases, so does the embodied carbon.

Increasing strength of concrete

Increasing embodied carbon

Concrete specification	Embodied carbon factor ($kgCO_2e/kg$), A1-A3
C16/20 UK, 25% GGBS	0.087
C20/25 UK, 25% GGBS	0.093
C25/30 UK, 25% GGBS	0.100
C32/40 UK, 25% GGBS	0.120
C40/50 UK, 25% GGBS	0.138

Table 3.1 - Carbon factors for different common concrete specifications as recommended by the How to Calculate Embodied Carbon (2nd edition) guide published by the Institute of Structural Engineers. (Source: [Inventory of Carbon & Energy database](#))

However, for the structural design of retaining walls, an increase in concrete strength class has little influence on reducing the volume of concrete required. The proportion of cement replacement material such as Ground Granulated Blast-furnace Slag (hereafter GGBS) plays a much more significant role in the embodied carbon of the concrete element as shown in Table 3.2.

Concrete specification	Embodied carbon factor ($kgCO_2e/kg$), A1-A3
0% GGBS CEM 1 UK, C32/40	0.1495
25% GGBS CEM 1 UK, C32/40	0.1204
50% GGBS CEM 1 UK, C32/40	0.0888

Table 3.2 - Embodied carbon factors for A1-A3 modules C32/40 of varying GGBS proportions. (Source: [Inventory of Carbon & Energy database](#))

While other cement replacement materials such as fly ash and limestone are available, Ground Granulated Blast Furnace Slab (GGBS) is the most readily available cement replacement material in the UK. Figure 3.3 shows an example of the embodied carbon of a basement proposal using different proportions of GGBS in the concrete mix.

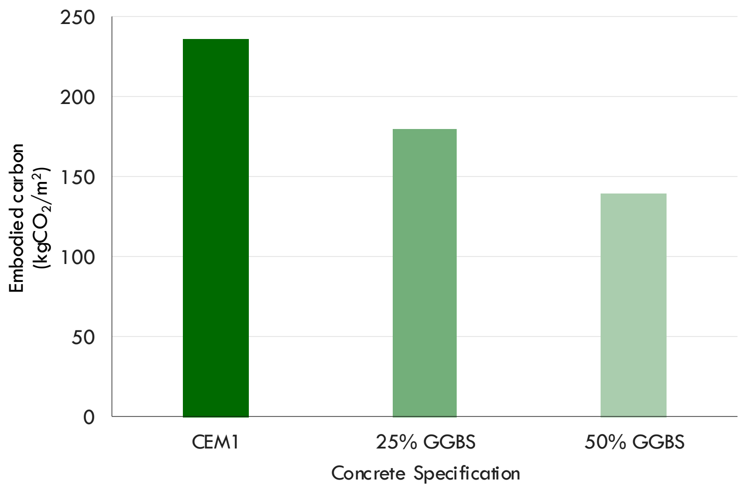


Figure 3.3 - Embodied carbon (A1-A3) per unit floor area for an unpropped retaining wall of 4m retained height and 150kN/m^2 bearing capacity. Embodied carbon figures shown for retaining walls only.

Evaluation of structural design parameters | Cement Specification (2/2)

However, it should be noted that these embodied carbon values only capture the A1-A3 carbon modules i.e. from cradle to gate. The contributions of the construction stage emissions are not included in these figures. As the proportion of GGBS increases in a concrete mix, the rate of strength gain of the concrete reduces. This is seen at a heightened degree when the proportion of GGBS exceeds 25%. Slower strength gain is likely to be associated with an elongated construction phase which, in turn, is likely to be associated with increased carbon emissions. For example, machinery will need to operate for longer periods and construction workers will need to commute more to and from site.

Additionally, GGBS is becoming less and less readily available in the UK due to the diminishing use of blast furnaces and the transition to electric arc furnace technology. Therefore, structural engineers may specify 50% GGBS concrete that cannot be procured. This may result in a more carbon-intensive concrete being used during the construction stage for which the embodied carbon could not be accounted for.

It is recommended that there should be a focus on promoting lean design of concrete elements e.g. optimising concrete volumes, rather than relying on new-age cement mixes or technologies to reduce the embodied carbon expenditure.

Key findings & considerations:

- Request that concrete specifications (strength class and cement replacement material proportions) are declared as part of planning applications
- Challenge the concrete specifications for retaining walls that exceed C32/40 and GGBS proportions that exceed 25%.
- Encourage structural engineers to optimise the concrete strength class across all concrete elements. The slab elements may not require the same concrete strength as the retaining walls, for example.

Minimum and maximum embodied carbon figures

Bottom-line figures

All iterations of the basement design with varying design parameters (retained height, water table depth, bearing capacity, etc.) were reviewed to identify the combination of design parameters that gave the minimum and maximum embodied carbon values. The minimum and maximum embodied carbon values per unit of gross internal floor area is shown in Figure 3.4 for propped and unpropped basements.

For propped basements, the maximum value is associated with a basement with 5m retained height, 100 kN/m^2 bearing capacity and a suspended basement floor slab. This maximum value is shown graphically in Figures 5.A.11 and 5.A.12. Meanwhile, the minimum propped embodied carbon is found in the basement design of a 1m retained height, 200kN/m^2 bearing capacity and ground-bearing basement floor slab. This is shown graphically in Figures 5.A.8 and 5.A.9.

Similarly, the maximum embodied carbon for the unpropped design is related to a retained height of 5m, a bearing capacity of 150kN/m^2 and a suspended basement floor slab. This is shown graphically in Figures 5.A.5 and 5.A.6. Minimum values for the unpropped basements belong to a retained height of 2.8m, a bearing capacity of 200kN/m^2 and a ground-bearing basement slab, as shown in Figures 5.A.2 & 5.A.3.

Both basement systems exhibit a wide range of embodied carbon values with a difference of as much as **270 kgCO_2e/m^2** for the unpropped case. This validates the statement that basement design can vary significantly with a change in design parameters and, in response to this, supports the argument that the reduction of embodied carbon is inherently controlled by design. It is important to note that the minimum values will vary from case-to-case but the intent is to optimise the design for minimal carbon emissions impact.

Key findings & considerations:

- Include these equivalency values within the planning guidance in order to contextualise the embodied carbon expenditure of a typical basement to new applicants. However, these equivalency values should not take the role of benchmarks or targets.

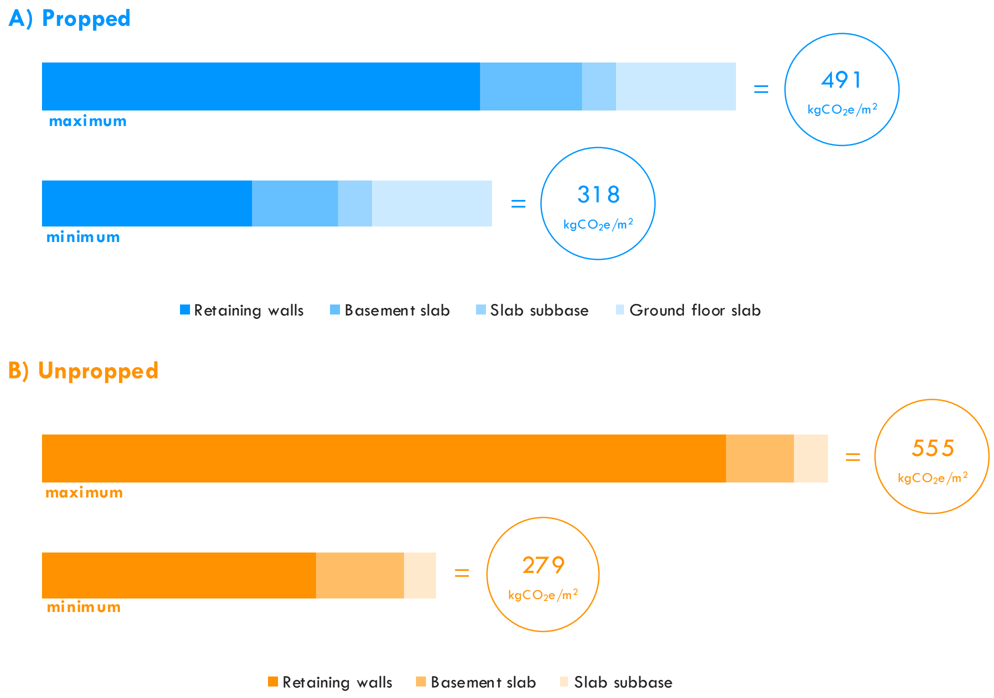


Figure 3.4 – Visual representation of the upfront embodied carbon ranges of a propped compared to an unpropped basement construction based on a basement gross floor area of 80m^2

What do the carbon numbers mean in real terms?

Limitations of the study

Limitations of the study

It is extremely important to note that this study has only captured a narrow snapshot of the embodied carbon figures that can be expected when a new basement is constructed within a terraced house. While efforts have been made to adopt conservative and realistic assumptions, it is not feasible to consider all possible scenarios. Therefore, it is advised that these results should be viewed with a degree of caution.

It is likely that there will be cases where applicants will present embodied carbon figures that fall outside of the figures presented in this report e.g. basement size. For this reason, the embodied carbon of a basement proposal should not only be assessed against a quantitative metric.

Additionally, it is well-established that the embodied carbon of a new-build increases exponentially as the project progresses through its construction phase. This has not been captured in this study as only the A1-A5 carbon modules have been considered. Efforts should be made to ensure this increase is minimised and accounted for as early in the design stage as possible.

4.0

Assessment of Alternative Options

This section outlines the alternative approaches to counterbalance the embodied carbon of basement extensions.

Targeted Retrofit

Policy D6 – Basements in the Draft New Camden Local Plan (2024) requires applicants to demonstrate that proposals for basements have sought to offset the carbon impact of the construction of the basement (E.iii). To assess the feasibility of this strategy, a viable pathway to mitigate the high embodied carbon of basements has been explored. An example could be that a simplified comparison is undertaken of the operational carbon emissions from the original house without any interventions, and with the addition of the basement extension; with and without retrofit interventions. Key assumptions and limitations are detailed on the next page.

Targeted retrofits outweigh carbon costs of basement extensions

Figure 4.1 shows the embodied carbon associated with an example new basement extension, as well as the consequent increase in direct carbon emissions due to the rise in operational energy required to support the additional floor area.

Figure 4.2 shows that by implementing targeted retrofit measures to the existing building, we can not only compensate for the additional carbon emissions in the first 8 years after the construction of the basement but also contribute to long-term energy savings and increased building energy performance. The direct carbon savings on the operational energy as a result of the heat pump clearly outweighs the embodied carbon of the heat pump and additional basement combined, across 20 years.

Please note 1000 $kgCO_2e$ is equivalent to 1 tCO_2e

Key

- Embodied carbon of a new basement extension
- Operational carbon of the existing terrace house
- Operational carbon of the existing terrace house with the basement
- Operational carbon savings which counterweigh the initial embodied carbon of the basement extension if the terrace house had an Air Source Heat Pump installed

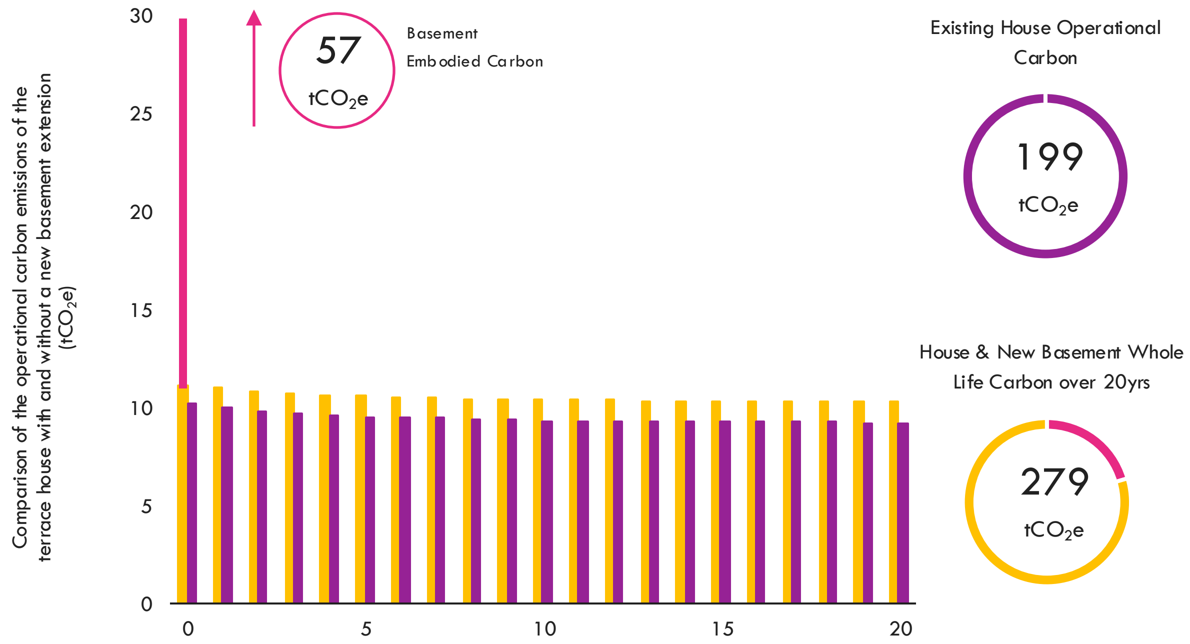


Figure 4.1 - shows the projected operational carbon emissions for the existing terrace house (orange), increase with basement extension (yellow), and surge in embodied carbon (pink).

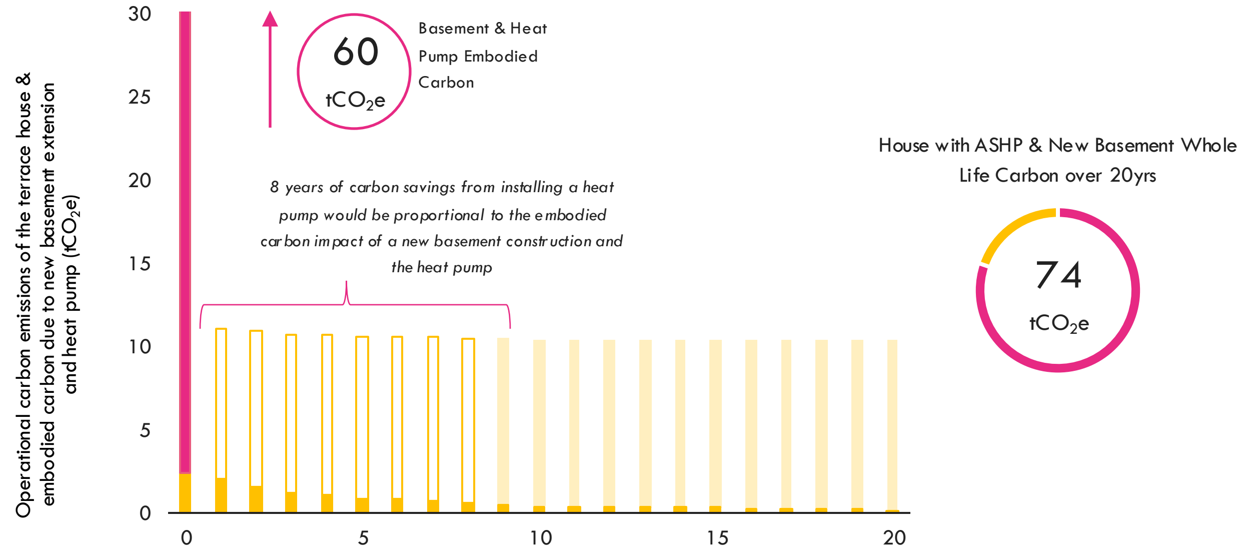


Figure 4.2 - shows the reduction in operational carbon with a heat pump installation. The carbon savings from the heat pump makes up for the embodied carbon of both the basement and heat pump within the first 8 years.

Targeted Retrofit | assumptions & limitations

Key assumptions and limitations

- The new basement extension is assumed to have the same footprint as the Terrace i.e. 80m^2 of basement floor and use a propped system which results in 57 tCO2e of embodied carbon – focusing solely on the structural elements
- The proposed retrofit measure evaluated in this exercise is an air source heat pump installation to the existing house based on the baseline results for the terrace house as shown in Figure 4.2. The heat pump was shown to be the most worthwhile retrofit measure from an energy efficiency and carbon savings perspective. A typical individual heat pump along with the associated upgrade of equipment required would result in an additional estimated 2-3 tCO_2e of embodied carbon.
- This exercise excludes the emissions associated with heat pump refrigerant leakage across the years, as this would be marginal compared to the operational emissions, and to maintain simplification
- The boundary of this exercise is limited to 20 years as the difference in operational energy consumed annually, should the house remain the same, would be eventually marginal as the grid decarbonises.

Offsetting embodied carbon

Offset the residual carbon as a last resort

When all feasible measures to reduce the embodied carbon of a basement extension have been exhausted, there may still be residual carbon that needs to be addressed. Financial offsetting provides a mechanism to balance the basement carbon footprint by investing in projects that reduce or capture carbon emissions elsewhere.

The financial contributions could be directed into a carbon offset fund managed by the council. This fund supports various environmental projects that aim to reduce or capture carbon emissions, such as reforestation, renewable energy projects, or energy efficiency programs within the community.

Implementation Process

Financial offsetting should be viewed as a last resort after all design and retrofit options have been explored and implemented. It is crucial to avoid reliance on offsets as an easy way out, thereby ensuring genuine efforts are made to reduce carbon emissions at the source.

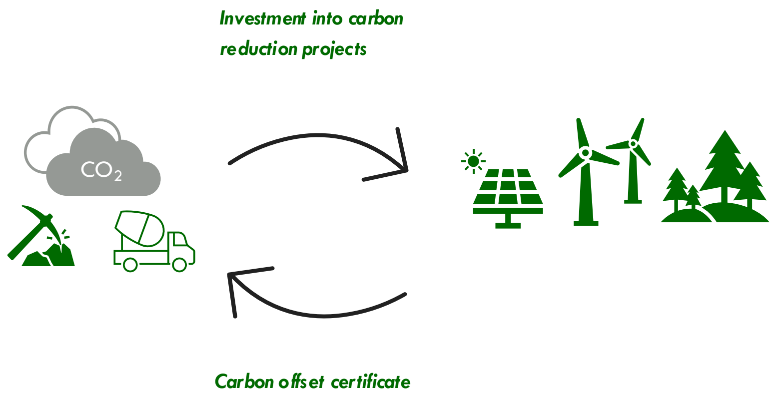


Figure 4.3 - Illustration of offsetting mechanism

Alternative extension | Embodied carbon of an extension vs a basement

As briefly mentioned, one of the biggest advantages of a new basement is the heightened land-occupancy efficiency. However, it can be argued that the same degree of efficiency can be achieved with an upward extension on an existing property i.e. a loft conversion with a new roof, provided the same increase in floor area is achieved.

This has been briefly explored to better understand the embodied carbon implications of a new basement in comparison to an above ground extension with an equivalent floor area. In supporting the planning guidance, exploring alternatives like an upward extension will allow new applicants to contextualise the high embodied carbon expenditure of a new basement. Additionally, providing applicants with alternative options will ensure they are not entirely discouraged from executing new residential developments out of fear of significant environmental implications.

Findings

The embodied carbon of a loft conversion plus a new roof was found to equal **267 kgCO_2e/m^2** . As shown in Figure 5.1, this is outside the range of the embodied carbon of a new basement for both propped and unpropped cases. While the value is comparable to the lower bound value of an unpropped basement, the lower bound value corresponds to a basement of 1m retained height and 250 kN/m^2 bearing capacity. In other words, a very shallow basement on very good soil – which will rarely be proposed - required more embodied carbon than an above-ground floor extension for the same floor area.

Evaluation of findings

The lower carbon value associated with the loft conversion can be attributed to two factors. Firstly, as previously mentioned, above-ground structure can typically be built in predominantly steel or timber. This was the case for the model used in the study where there was no requirement for concrete within the structural design.

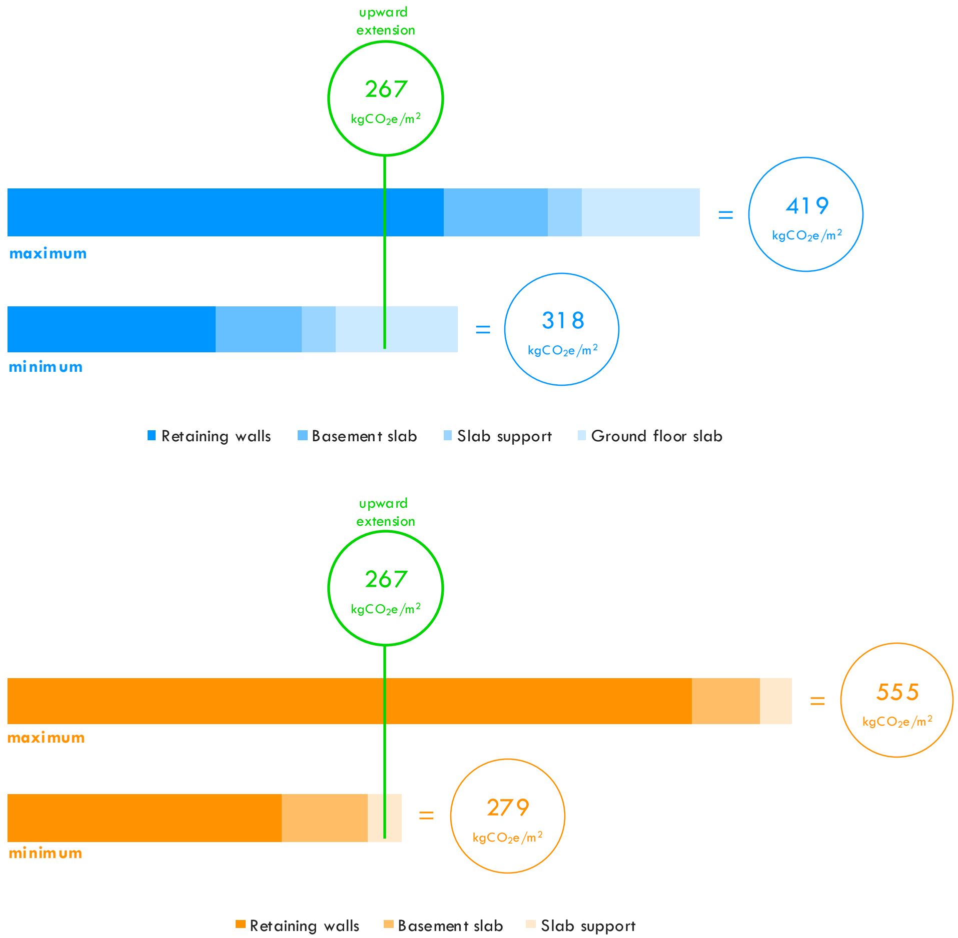


Figure 5.1: Visual representation of the embodied carbon of a typical upward extension compared to the range of embodied carbon for propped (top) and unpropped (bottom) basements.

Both timber and steel are associated with lower embodied carbon values for their relative strength-to-weight ratios. Secondly, the design of timber roofs, timber floors and steel beams is better understood by structural engineers, generally. Therefore, there is greater comfortability in implementing leaner design practices here, something that is not commonly seen with basement design.

5.0

Key findings

This section provides a summary of the key findings of the study and sets out several options that the council can consider moving forward

Summary of key findings

Key findings & considerations

- It is recommended that applicants submit embodied carbon figures for their new basement structural proposals as part of the BIA and the latest version of the IStructE Structural Carbon Tool should be used to conduct the calculations.
- Request both quantitative and qualitative information for the embodied carbon expenditure of a new basement application. Quantitative information may be in the form of bottom-line carbon figures while the qualitative information may take the form of a written statement of justification outlining the design decisions and assumptions made.
- If a written statement of justification is found to require excessive work for both applicants and auditors, a questionnaire pro forma may be a useful alternative.
- If the embodied carbon figures presented in this report are to be adopted as part of the planning guidance, they should be implemented as benchmarks rather than target values.
- Present all assumptions made in this study in the planning report and welcome applicants to challenge assumptions to justify when their embodied carbon values fall outside the benchmark. Assumptions are presented in Appendix 5.
- Implementing a robust benchmark based on this study alone is very difficult. A more efficient course of action could be to include the implementation of a more lenient benchmark to begin with and, as more embodied carbon figures are submitted as part of basement planning applications, refine it until it eventually becomes a target.
- Require opening-up investigations to be conducted during the planning stage to determine existing loadings, structural elements including foundations and the general ground condition to increase design certainty at the planning stage
- Request pre- and post-construction embodied carbon figures. This should capture changes in structural dimensions, architectural proposals and material specifications. At a minimum, a simple calculation of the change in concrete volume to the basement structure, and any changes to the concrete mix specification, should be submitted.

Opportunity to increase the BIA scope

Adding embodied carbon to the list of issues which the BIA needs to address is logical: it would not add a disproportionate amount of work/costs to the current process and would not require a different set of skills. It would also encourage better structural design through the careful use of concrete.

However, it is important to ensure that the following at a minimum are addressed:

- Clearly define the scope of the embodied carbon appraisal (e.g. structure only)
- Consider whether a post-completion pro-forma could also be required to confirm that recommendations identified during the BIA have been delivered
- Detail check on the specifics of the proposed works (e.g. concrete specs, thickness of walls, etc.).

Additional planning guidance is likely to be required to ensure applicants fully understand the requirements and considerations that need to be made.

6.0

Appendix

A. Embodied carbon assessment results

B. Assessment assumptions

Embodied carbon modelling results

Unpropped retaining wall with ground-bearing basement slab

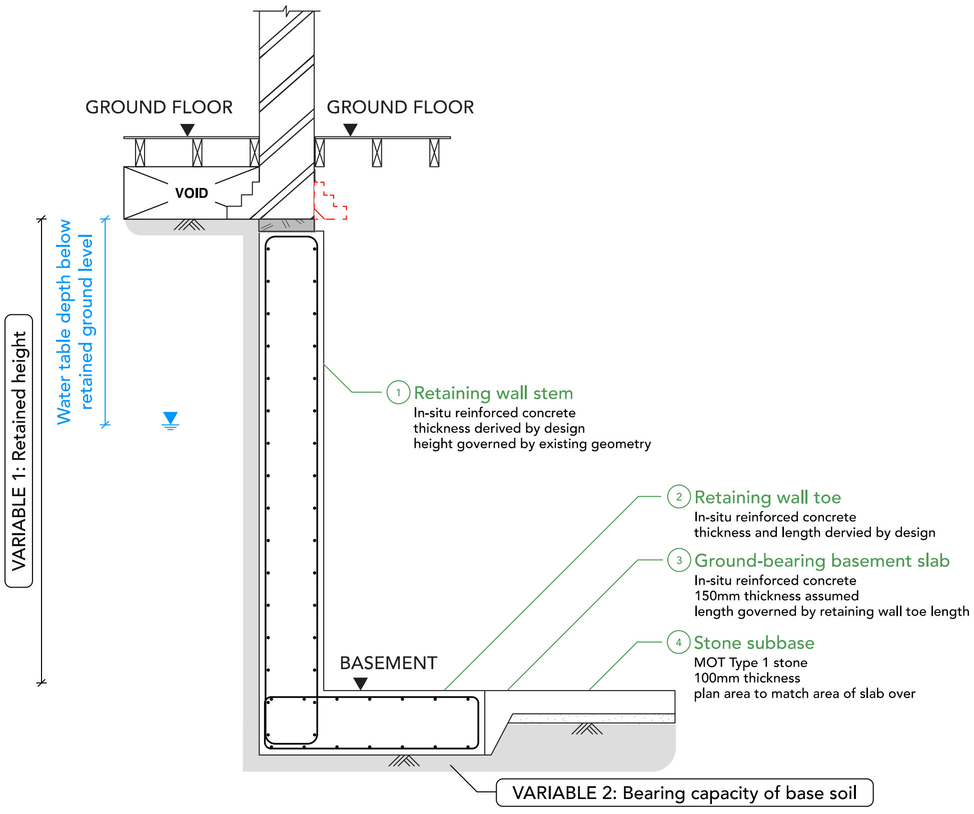


Figure 5.A.1- Schematic diagram of unpropped retaining wall and ground-bearing floor slab model used to understand relationship between embodied carbon (A1-A3) and the variation of two design parameters – retained height (m) and bearing capacity (kN/m²).

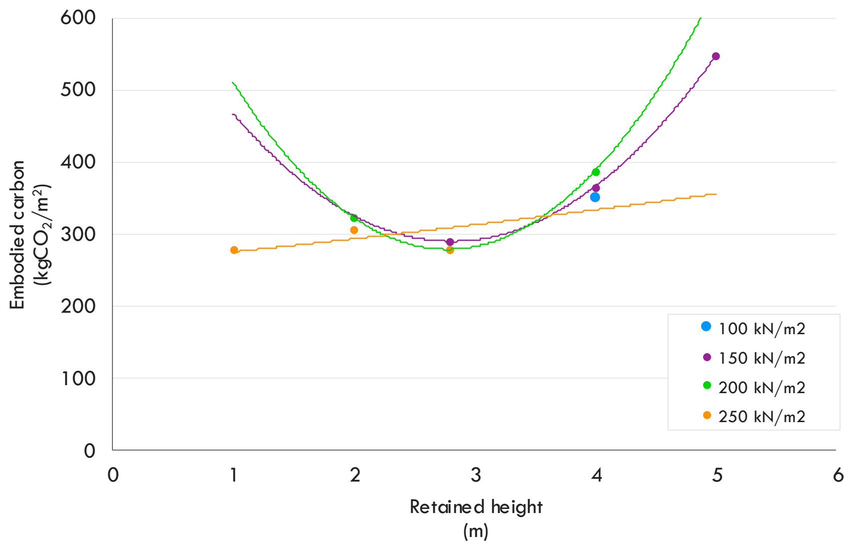


Figure 5.A.2 - Embodied carbon (A1-A3) per unit floor area for unpropped retaining walls of increasing retained heights with a ground-bearing basement slab. Results shown for a range of bearing capacities from 100 – 250 kN/m²

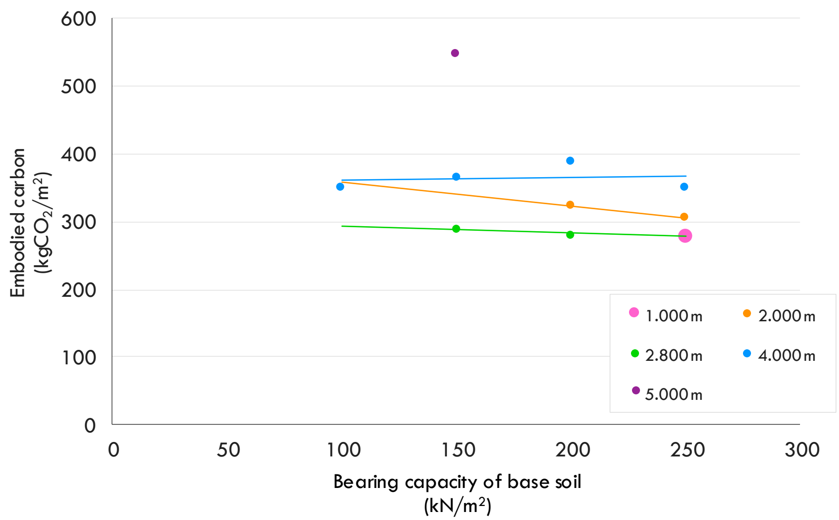


Figure 5.A.3 - Embodied carbon (A1-A3) per unit floor area for unpropped retaining walls with a ground-bearing basement slab and increasing bearing capacity. Results shown for retained heights ranging between 1.000 – 5.000m

Embodied carbon modelling results

Unpropped retaining wall with suspended basement slab

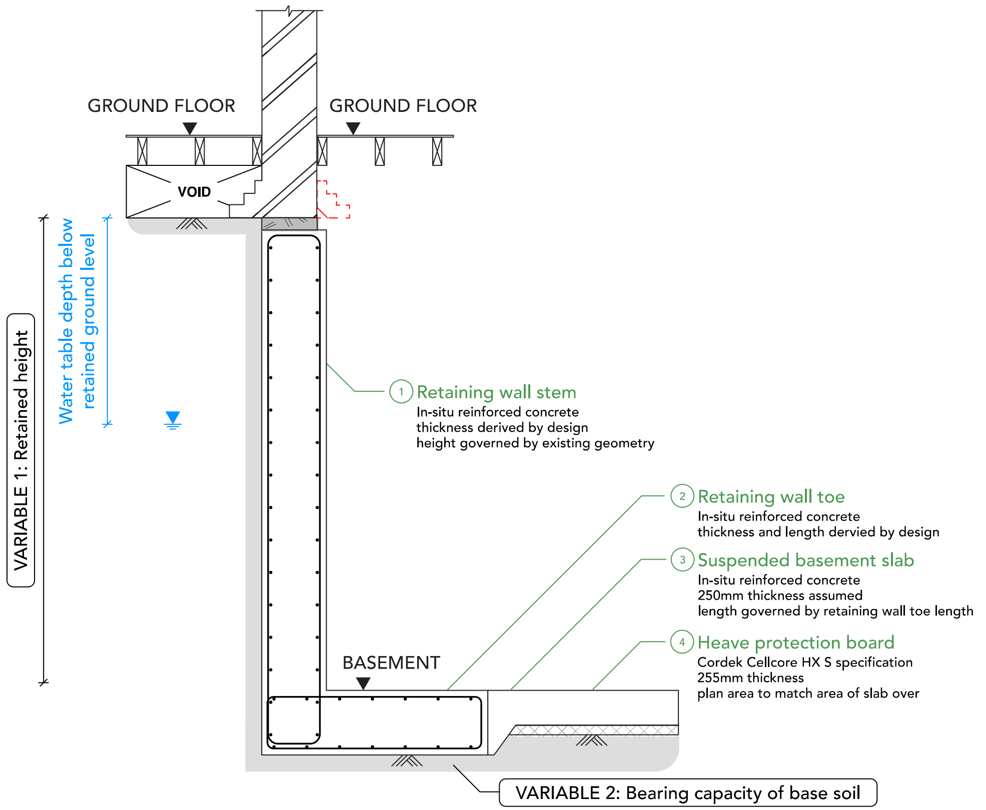


Figure 5.A.4 - Schematic diagram of unpropped retaining wall and suspended floor slab model used to understand relationship between embodied carbon (A1-A3) and the variation of two design parameters – retained height (m) and bearing capacity (kN/m²).

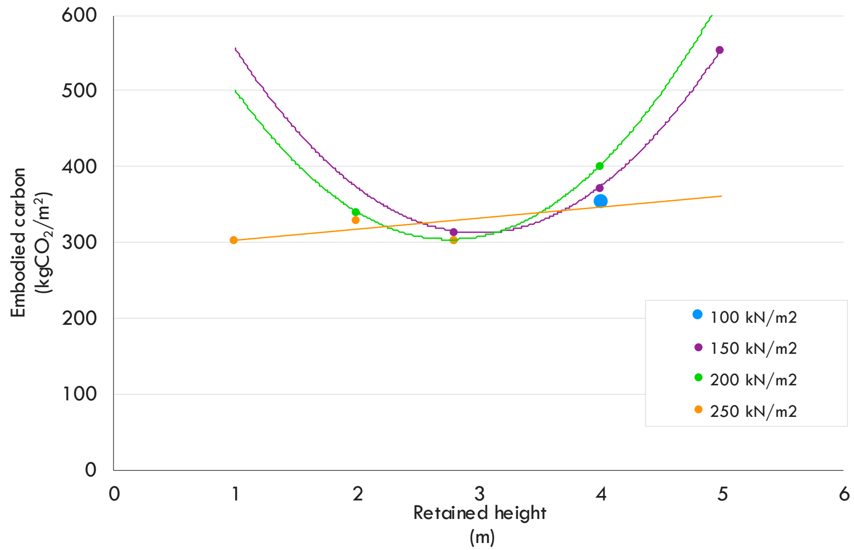


Figure 5.A.5 - Embodied carbon (A1-A3) per unit floor area for unpropped retaining walls of increasing retained heights with a suspended basement slab. Results shown for a range of bearing capacities from 100 – 250 kN/m²

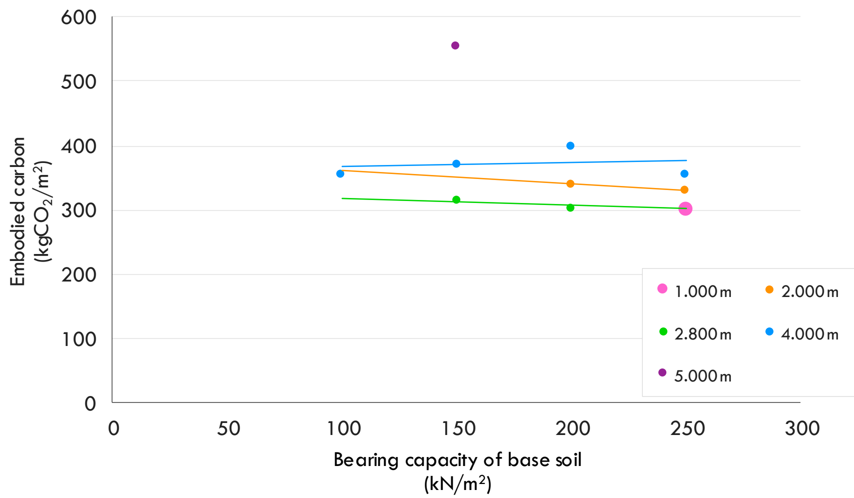


Figure 5.A.6 - Embodied carbon (A1-A3) per unit floor area for unpropped retaining walls with a suspended basement slab and increasing bearing capacity. Results shown for retained heights ranging between 1.000 – 5.000m

Embodied carbon modelling results

Propped retaining wall with ground-bearing basement slab

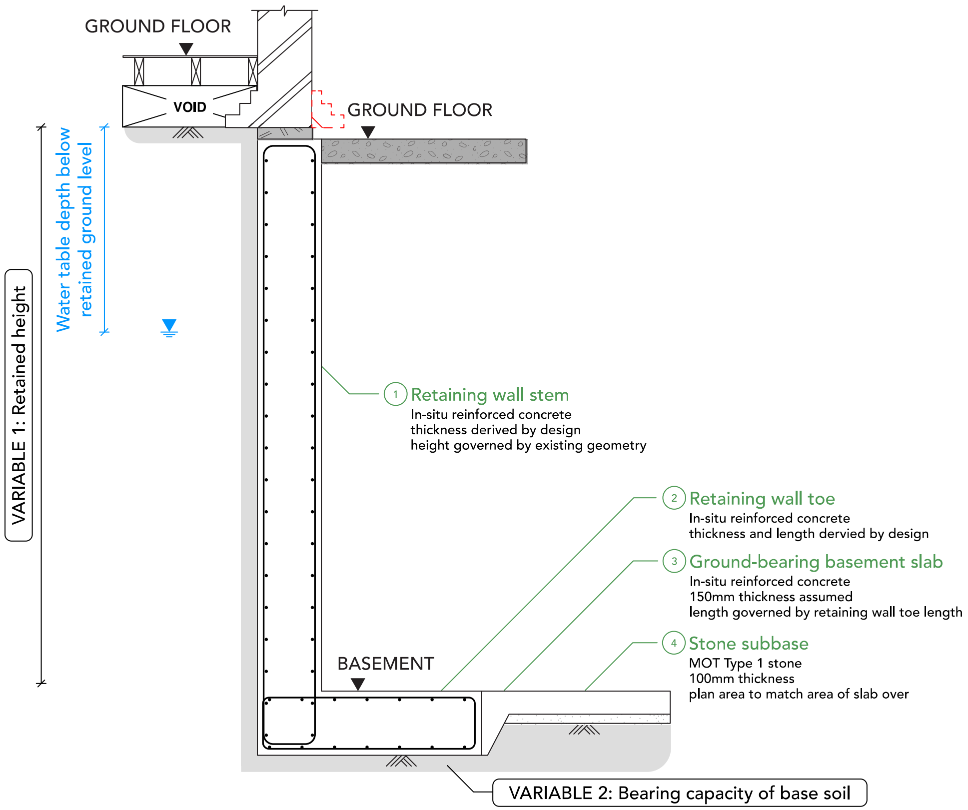


Figure 5.A.7 - Schematic diagram of propped retaining wall and ground-bearing floor slab model used to understand relationship between embodied carbon (A1-A3) and the variation of two design parameters – retained height (m) and bearing capacity (kN/m²).

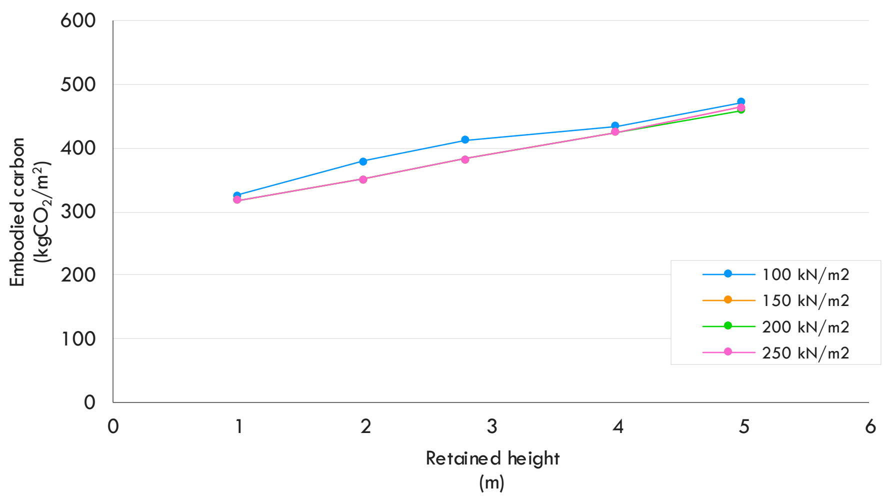


Figure 5.A.8 - Embodied carbon (A1-A3) per unit floor area for propped retaining walls of increasing retained heights with a ground-bearing basement slab. Results shown for a range of bearing capacities from 100 – 250 kN/m2

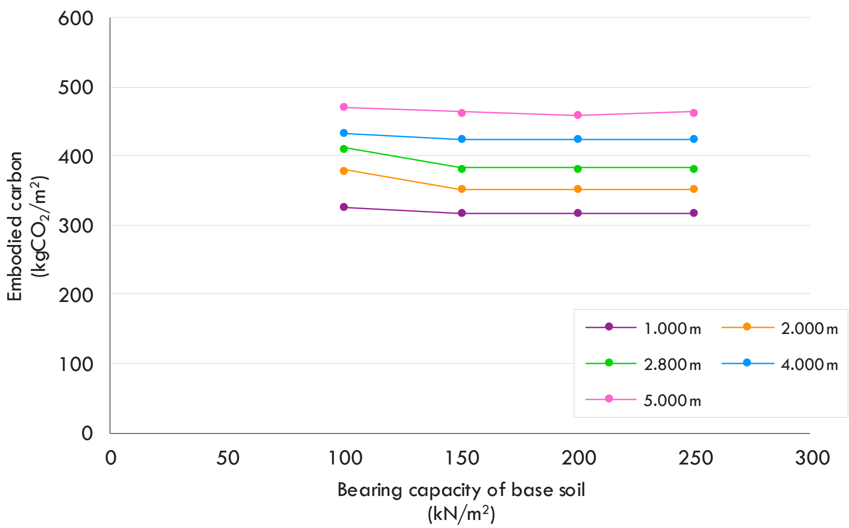


Figure 5.A.9 - Embodied carbon (A1-A3) per unit floor area for propped retaining walls with a ground-bearing basement slab and increasing bearing capacity. Results shown for retained heights ranging between 1.000 – 5.000m

Embodied carbon modelling results

Propped retaining wall with suspended basement slab

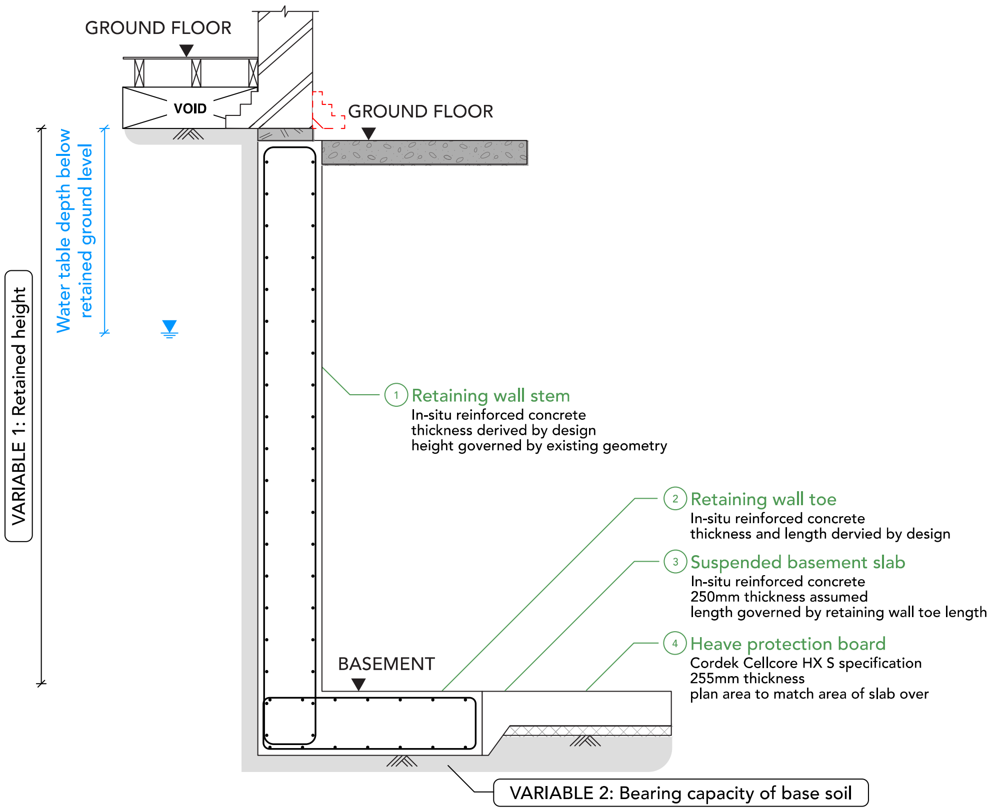


Figure 5.A.10 - Schematic diagram of propped retaining wall and suspended floor slab model used to understand relationship between embodied carbon (A1-A3) and the variation of two design parameters – retained height (m) and bearing capacity (kN/m²).

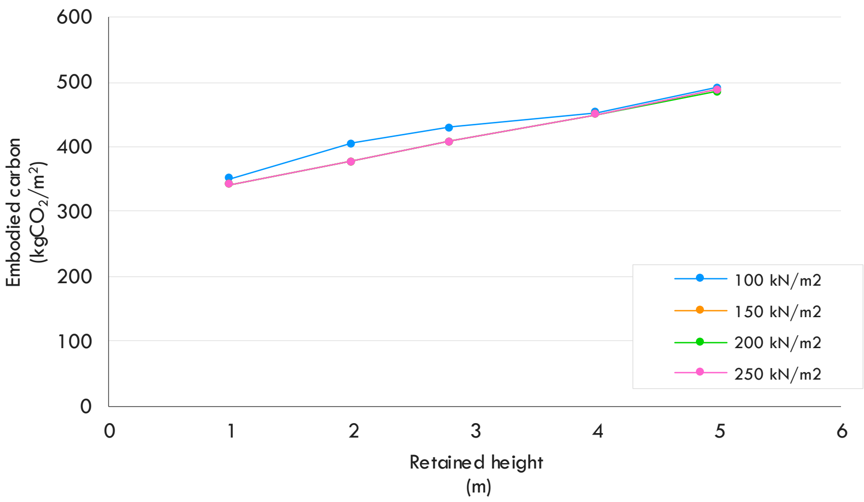


Figure 5.A.11 - Embodied carbon (A1-A3) per unit floor area for propped retaining walls of increasing retained heights with a suspended basement slab. Results shown for a range of bearing capacities from 100 – 250 kN/m²

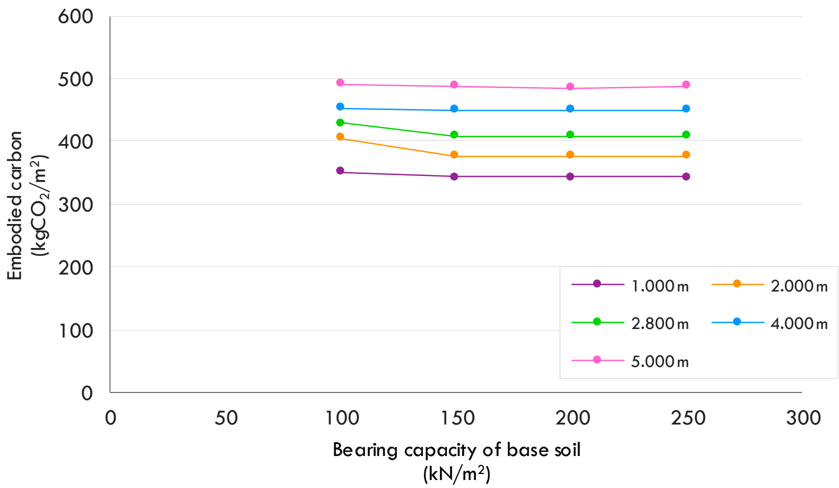


Figure 5.A.12 - Embodied carbon (A1-A3) per unit floor area for propped retaining walls with a suspended basement slab and increasing bearing capacity. Results shown for retained heights ranging between 1.000 – 5.000m

Embodied carbon modelling results

Variation in water table depth below retained ground level

for 4.000m retained height & 150 kN/m² bearing capacity with a ground-bearing basement floor slab

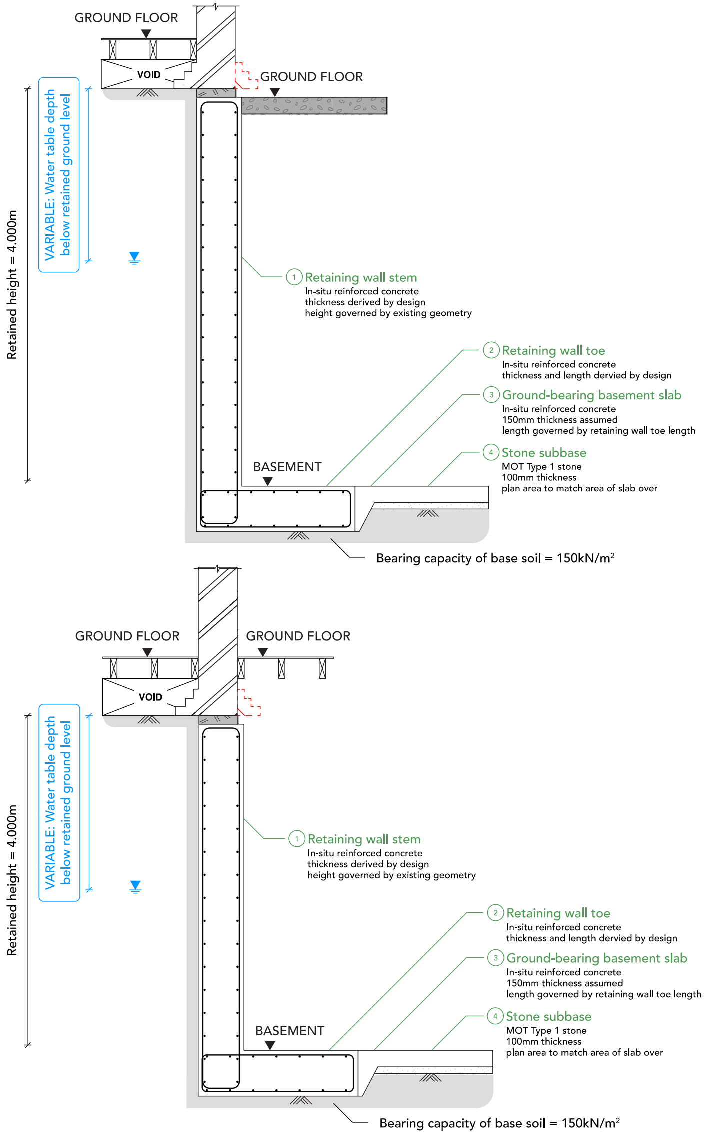


Figure 5.A.13 - Schematic diagram of propped (top) & unpropped (bottom) retaining wall models with fixed retained height and bearing capacity values used to understand relationship between embodied carbon (A1-A3) and the variation of water table depth (m).

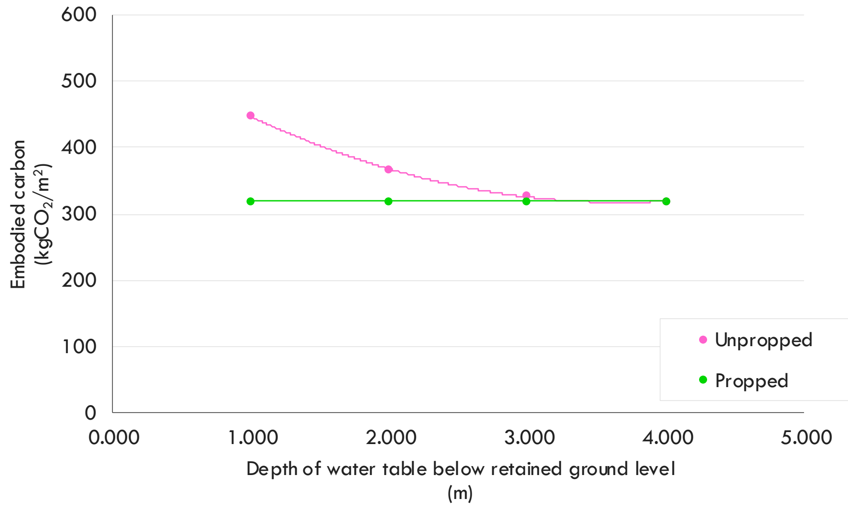


Figure 5.A.14 - Embodied carbon (A1-A3) per unit floor area for a propped and unpropped retaining wall of 4.000m retained height and 150kN/m² bearing capacity with varying depth of water table below retained ground level.

Cement specification with varying proportions of GGBS

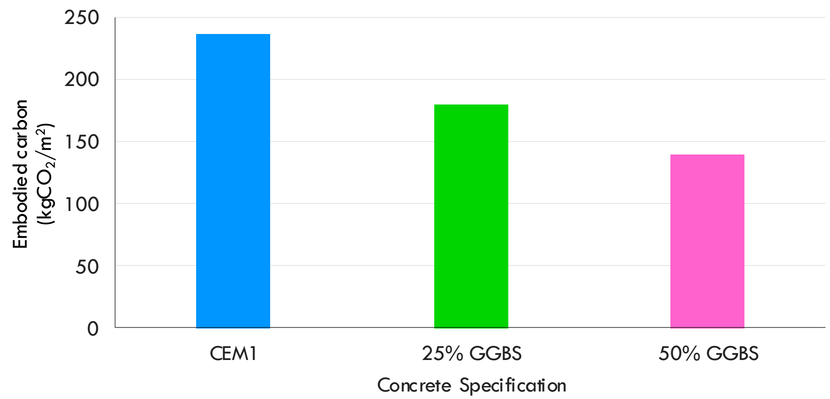


Figure 5.A.15 - Embodied carbon (A1-A3) per unit floor area for an unpropped retaining wall of 4.000m retained height and 150kN/m² bearing capacity. Embodied carbon figures shown for retaining walls only.

Embodied carbon modelling assumptions

Construction Data	• Existing foundations are brick corbel footings bearing at highest existing soil level • 215mm thk. wall thickness along party wall line • 343mm thk. wall thickness along front and rear elevations, decreasing to 215mm thk. above first floor level • All walls are of solid masonry wall construction • Structure and load paths are mirrored along party wall line in both neighbouring properties • Structural slab level is uniform across basement level • Building is not within a significant flood risk zone • Existing floor structure at ground floor and above is of timber construction • No neighbouring basements in the existing condition • Basement design permits Category 1 – Very Slight Damage to be achieved on the Burland Scale • £200,000 project value for basement construction only [1]
Carbon Calculations	• The carbon calculations will only consider the structural elements within the basement for A1-A3 basements. This excludes floor/wall finishes, internal partitions, waterproofing methods, M&E fixings, waterproofing. Note, this list is only indicative, not exhaustive.
Design Data	• Load-bearing soil stratum comprising London Clay soil type with a bearing capacity of 150kN/m [2] • 40 - 60 (high) Plasticity Index of base soil • Soil profile is the same for retained and load-bearing base soil • Toe of retaining walls is suitable to act simultaneously as the basement floor slab • C32/40 concrete strength class with 25% GGBS content • The same concrete strength class/concrete mix is used across all RC elements • Reinforcement ratio equal to 110kg of steel rebar per m^3 of concrete • Ground water level occurs at a uniform depth equal to 1.000m below retained ground level • Special foundations are permitted along party wall lines • 150mm deep ceiling zone below ground floor joists • 200mm deep finishes zone above basement floor slab • 2.900m clear height required uniformly across basement level • Soil profile is uniform, and soil behaviour is idealistic • Worst-case retained soil height taken in design • Waterproofing measures address in architectural design. No measures taken within structural design • New & existing timber joists at ground floor level are 47mm wd. x 175mm dp. @ 350 c/c [3]

Embodied carbon modelling assumptions

Footnotes
1 Project value (£) is required to calculate the embodied carbon expenditure associated with the construction phase assuming a directly proportional relationship. Lower embodied carbon figures are usually associated with precast/off-site construction
2 Assumed soil profile and bearing capacity value based on Code of practice for foundations - BS8004:1986 & Camden geological, hydrogeological and hydrological study - Guidance for subterranean development by Arup, November 2010
3 Existing timber floor joists are typically of this section size and spacing for a property of this age. For comparative purposes, it is assumed that new timber joists are of the same section size and spacing

C. Key concepts and glossary

Embodied carbon in the wider carbon context

The making of materials, their transport, repair and deconstruction affects how much carbon is associated with them. This is a summary of the key boundaries for embodied carbon and the terms associated with them.

Upfront embodied carbon

Upfront embodied carbon refers to the greenhouse gas emissions associated with material and construction stages: raw material supply, manufacture, transport and construction of all building elements.

Life cycle embodied carbon

Life cycle embodied carbon includes both upfront embodied carbon and the embodied carbon associated with:

- In-use - maintenance, replacement and refrigerant leakage.
- End of life - waste processing of demolition/deconstruction and disposal of any products.

Operational carbon

Operation carbon refers to the emissions associated with energy and water use during operation.

User carbon

User carbon covers the emissions from user activities, outside of the use of energy and water emissions from the operation of the building. An example includes transport or vehicle charging. This module is typically outside the remit of building design.

Whole life carbon (WLC)

For buildings, whole life carbon is the sum of life cycle embodied carbon and operational carbon.

Circular economy/beyond life cycle

A circular economy seeks to ensure materials can be re-used again and again and are ultimately diverted from landfill or incineration. This builds on embodied carbon principles, such as material re-use, recovery and recycling.

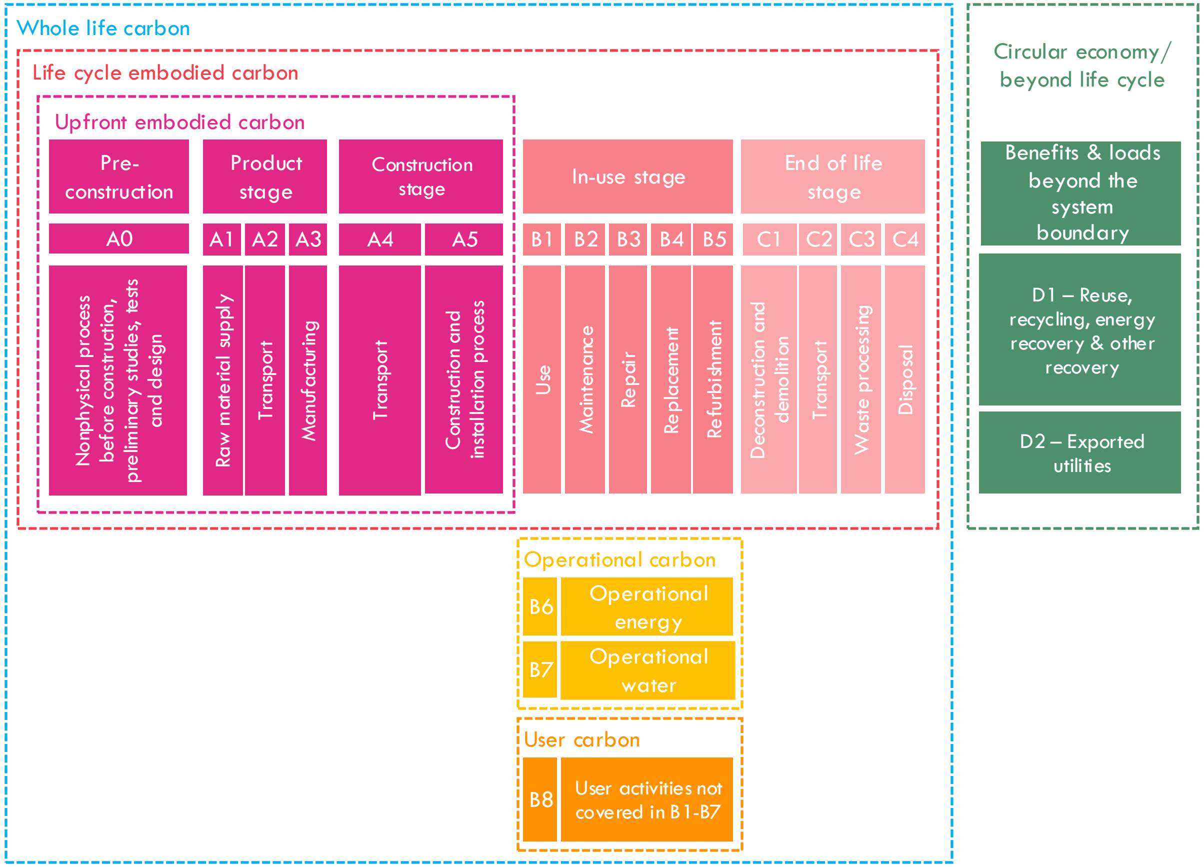


Figure 5.C.1 – Modular information for the different boundaries of the building assessment. This version of the diagram is adapted from a combination of the diagram from the BS EN 15978, RICS 2023 and LETI.

RICS 2023 definitions:

Greenhouse gases (GHGs) (often referred to as 'carbon emissions')

"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."

Carbon dioxide equivalent (CO_2e)

"A metric for expressing the impact of all greenhouse gases on a carbon dioxide basis."

Upfront and life cycle embodied carbon explained

Upfront embodied carbon

Upfront embodied carbon refers to the greenhouse gas emissions associated with material and construction stages: **raw material supply, manufacture, transport and construction** of all building elements.

Designers have the greatest ability to reduce upfront embodied carbon pre/post-planning by considering how a new building can be optimally designed and through the materials specified. This lends itself to benchmarking or target setting through planning policy, as it is the area most easily influenced by policy and addressed by client and design teams during the planning process.

Industry targets such as those by LETI are framed around upfront embodied carbon (modules A1-A5), and some recently adopted planning conditions also focus on these modules).

Module A0 (pre-construction stage) covers non-physical pre-construction activities, such as surveys and activities associated with the design of the asset. For buildings, these emissions do not normally have a significant environmental impact and therefore, are assumed to be negligible. Module A0 has a greater significance for larger infrastructure projects.

Life cycle embodied carbon

Life cycle embodied carbon includes both upfront embodied carbon (above) and the embodied carbon associated with the building in-use and at the end of life.

While design teams have some influence of the B and C modules in new build (through robust design, specification, and design for deconstruction), building owners and occupiers who will maintain and refurbish the building will have the most influence. This makes life cycle embodied carbon more complex to integrate into planning policy through target setting or benchmarking. Planning policies set around life cycle carbon may benefit from being more qualitative than quantitate. However, examples exist of planning policies and industry targets that consider life cycle carbon.

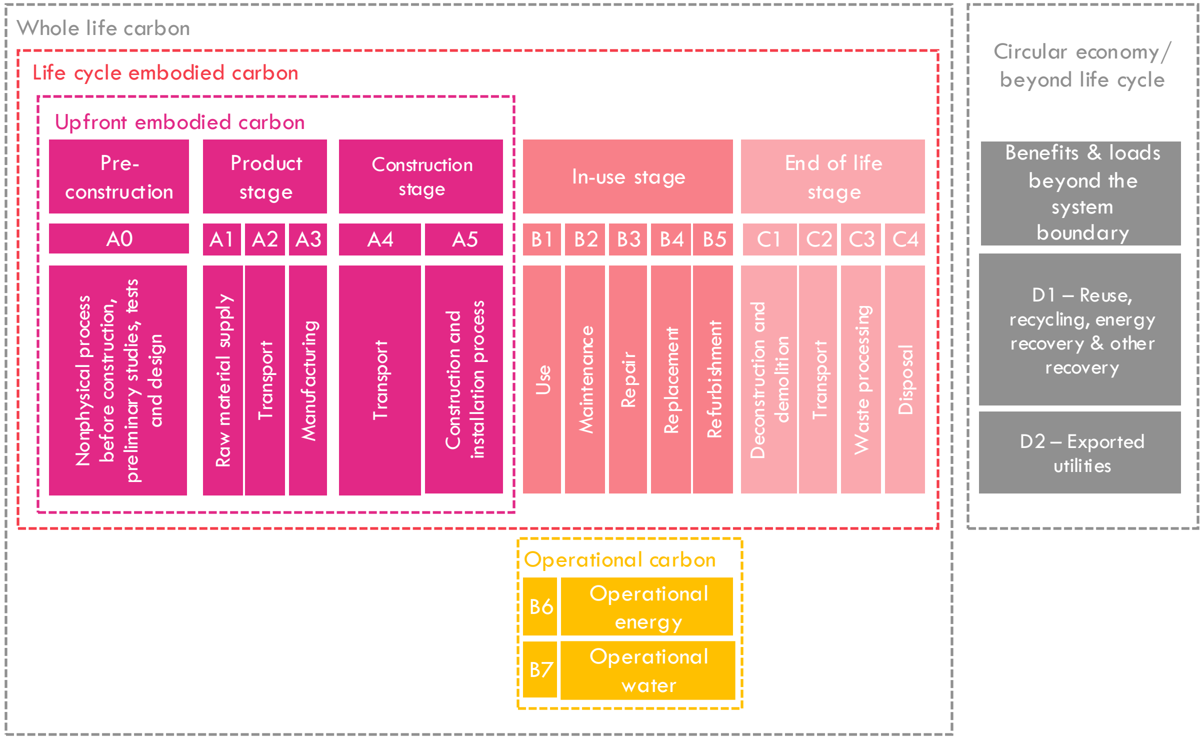


Figure 5.C.2 – Building assessment modules with a focus on life cycle and upfront embodied carbon. This version of the diagram is adapted from a combination of the diagram from the BS EN 15978, RICS 2023 and LETI.

RICS 2023 definition:

Life cycle embodied carbon

"The embodied carbon emission of an asset are the total green house gas (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 assumed to be zero for buildings)."

Upfront embodied carbon

"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."

Operational carbon explained

Operational carbon refers to the emissions associated with energy and water use of a building during its operation.

Operational carbon can and should be reduced through planning policy.

Balancing operational and embodied carbon

Decisions taken during the design of a building to improve operational carbon can have an impact on the resulting embodied carbon. Rather than considering operational carbon and embodied carbon separately a balance needs to be struck across all environmental considerations. Therefore, the focus should be to be on reducing operational carbon in support of ultra-low energy buildings alongside life cycle embodied carbon, as opposed to trading one instead of another.

Some considerations for reducing upfront embodied carbon, when ensuring the building achieves a net zero operational carbon include:

- An efficient building form almost always emits less upfront embodied carbon than a complex building form. It is also more likely to have lower operational carbon and reduce construction costs.
- Features such as: shading devices to reduce overheating; dual aspect dwellings for cross ventilation and daylight; green and blue roofs for sustainable urban drainage and biodiversity; or renewables should not be traded with embodied carbon. Instead, their impact should be recognised.
- Even though windows typically have a lower upfront embodied carbon than external walls, their total area should not exceed the recommended glazing-to-walls-ratio (north 10-15%, south 20-30%, east and west 10-20% for residential buildings), in order to keep a balance between upfront embodied carbon, the operational energy target, overheating and levels of daylight.
- When choosing different types of façade/external wall build-ups based on the lower upfront embodied carbon, energy performance parameters (u-values/airtightness) should always seek to achieve an ultra-low energy building.

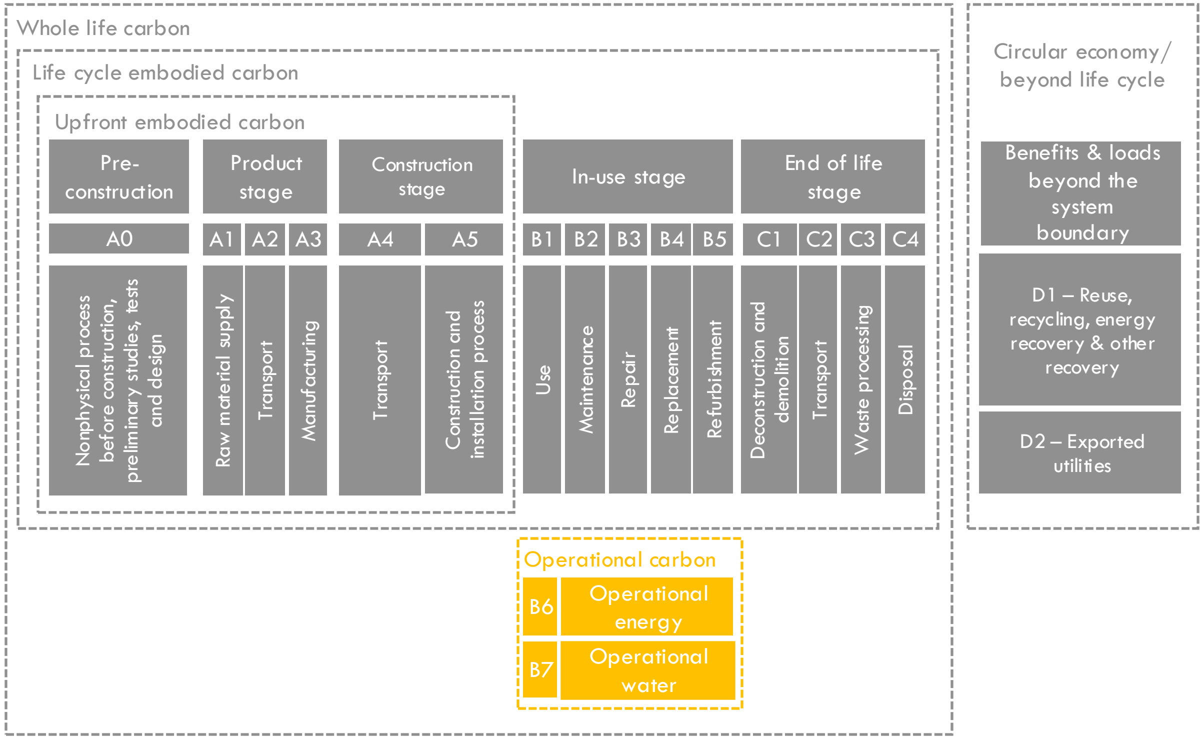


Figure 5.C.3 – Building assessment modules with a focus on operational carbon. This version of the diagram is adapted from a combination of the diagram from the BS EN 15978, RICS 2023 and LETI.

RICS 2023 definition:

> **Operational carbon**
>
> "Operational carbon – energy (module B6) refers to GHG emissions arising from all energy consumed by an asset in use, over its life cycle.
> - water (module B7) refers to GHG emissions arising from water supply and wastewater treatment for an asset in use, over its life cycle "

Whole Life Carbon explained

Whole life carbon is the sum of life cycle embodied carbon and operational carbon.

Bringing together operational and embodied carbon

As an industry we are still learning about the interrelationships between operational energy and embodied carbon and the uncertainties when bringing the two together in a Whole Life Carbon Assessment. In 2023, LETI shared a useful opinion piece on this topic.

The RICS Whole Life Carbon Assessment for the Built Environment translates international guidance (BS EN15978) into the UK context. The second edition was released in 2023 and is planned to come into effect in June 2024. This industry standard methodology combines operational and embodied carbon to create whole life carbon figures following industry best practice.

While there are benefits to calculating and reporting whole life carbon figures, if used without interrogation of the embodied and operational components separately they can mask poor design decisions and performance. Allowing embodied carbon to be traded with operational carbon.

The Greater London Authority (GLA) London Plan Policy SI 2 requires the full submission of Whole Life Carbon emissions. This currently applies to large scale, referable applications.

The campaign to introduce Part Z into the Building Regulations also proposes the mandatory measurement and reporting of Whole Life Carbon emissions.

The Southwark policy approach of calculating and reporting operational energy separately from embodied carbon has the benefit of ensuring each area is optimised and clearly demonstrated in design and construction. It may be that the reporting of whole life carbon figures in addition to the separate calculation of operational energy and embodied carbon could be a useful metric to consider as part of a stepped approach to policy.

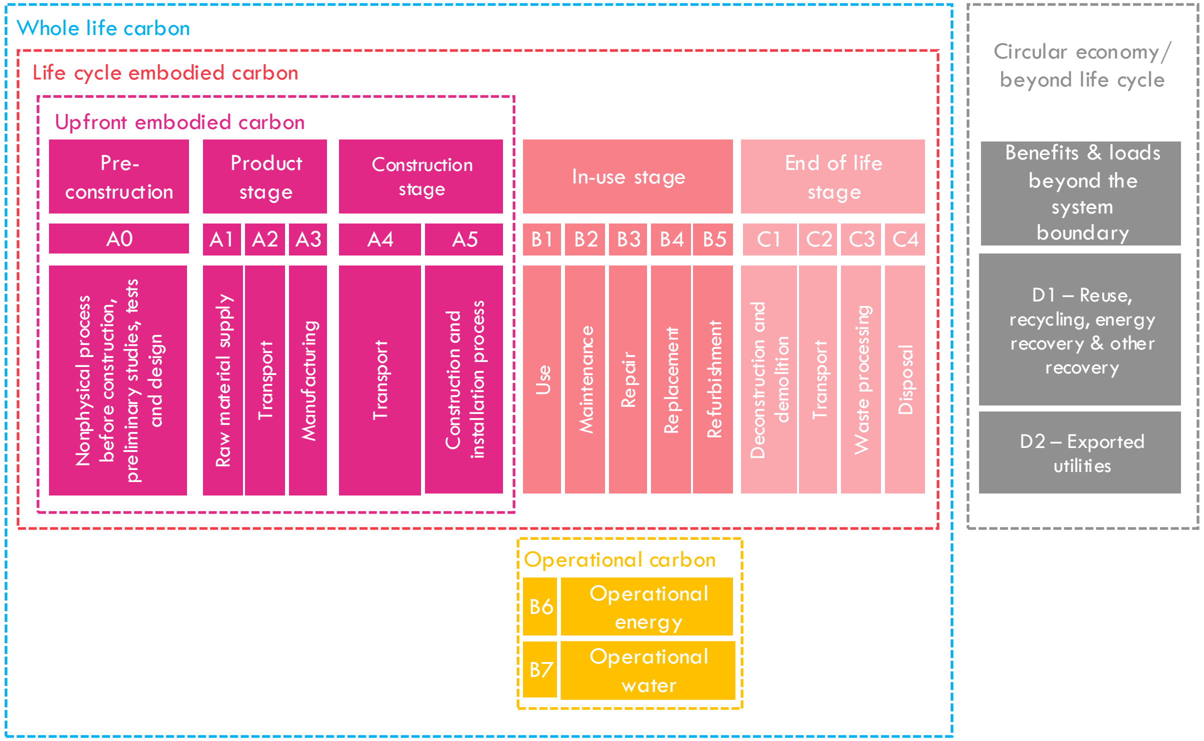


Figure 5.C.4 – Building assessment modules with a focus on whole life carbon. This version of the diagram is adapted from a combination of the diagram from the BS EN 15978, RICS 2023 and LETI.

RICS 2023 definition:

Whole life carbon

"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 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)."

Glossary

Basement Impact Assessment (BIA) - A required assessment to evaluate the potential effects of basement construction on ground stability, neighbouring properties, and environmental factors such as flooding.

Bearing Capacity - The capacity of soil to support the loads applied to the ground by a building structure, especially critical in basement design.

Biogenic/ sequestered 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.' Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*

Carbon Budget - The allowable amount of carbon dioxide emissions that can be released over a set period to meet climate targets.

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.' Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*

Environmental Product Declaration (EPD) – 'A document that clearly shows the environmental performance or impact of any product or material over its lifetime'.. Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*

Greenhouse Gases - atmospheric gases that trap heat in the Earth's atmosphere, causing the greenhouse effect. These gases allow sunlight to enter the atmosphere freely but absorb and re-emit infrared radiation (heat) back towards the Earth's surface, warming the planet.

Ground Granulated Blast-Furnace Slag (GGBS) - A cement replacement material that lowers the embodied carbon of concrete by reducing the amount of traditional cement required.

Life Cycle embodied carbon or 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.' Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*

Loading – a force that a structural element is required to support or resist and can include pressures from soils or weights from occupants and buildings

One Click LCA - ' One Click LCA is an all-in-one software to automate Life Cycle Assessment (LCA) and Environmental Product Declaration (EPD) generation. Schedule a time to get help for your LCA, EPD, and sustainability needs.' Source: *One Click LCA*

Operational carbon – 'Operational carbon – energy (module B6) refers to GHG emissions arising from all energy consumed by an asset in use, over its life cycle.' Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*

Retained Height - The vertical distance that soil is held back by a basement wall, affecting the wall's design and embodied carbon impact.

RICS Professional Standard (RICS PS v2 2023) – 'Sets 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.' Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*

Upfront embodied carbon – '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.' Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*

Whole life carbon (WLC) - '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).' Source: *RICS Whole life carbon assessment for the built environment, 2nd edition*