Westminster City Council

# EMBODIED CARBON EVIDENCE BASE

WSP

JANUARY 2024

CONFIDENTIAL

Westminster City Council

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WSP

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## *APPENDICES*

# 1 EXECUTIVE SUMMARY

This study has been a desk-based assessment, exploring the impact of common measures of reducing embodied carbon across 3 common building archetypes in The City of Westminster. This analysis found that achieving moderate improvements in embodied carbon (equivalent to LETI band C) can be done on cost parity with current building practices, and that achieving good embodied carbon (equivalent of LETI band B) was achievable with only a moderate 2-8% uplift in cost for office and mixed use buildings, by employing a mix of decarbonisation strategies such as: reduced grid spacing, removal of basements, timber and recycled materials. However, this analysis also found that achieving further reductions (LETI band A or lower) would require higher levels of timber or recycled materials not currently available on the market at scale.

This analysis shows that even adopting good practice design and high levels of material substitution, each of the buildings still will not achieve carbon reductions in line with UK Net Zero Target, 1.5 degrees and The Paris Agreement (LETI Band A or below). Achieving further reductions is much more likely to be made possible by re-using structure and materials from existing buildings, by promoting retrofit and the circular economy.

# 2 INTRODUCTION

In response to rising temperatures and growing public concern about the rise in greenhouse gas emissions, in 2019 the City of Westminster declared a climate emergency. Since then, the council has pledged to become a net zero council by 2030 and a net zero city by 2040. The City of Westminster Climate Emergency Action Plan states that the built environment make up to 86% of the carbon footprint of the city. To reduce the environmental impact of the built environment in the city the council have set ambitious goals and targets including "*retrofitting of buildings to cut their carbon emissions*" and requiring "*new developments achieve best practice standards*".

This report provides an evidence based embodied carbon study with the aim of setting suitable yet ambitious embodied carbon targets for new projects for Westminster City Council to achieve these aims. The project is framed around the existing report WSP completed as part of the West of England Spatial Development Strategy December 2021: Evidence Base for West of England Net Zero Building Policy: Embodied Carbon.[1]

[1] Evidence Base for West of England Net Zero Building Policy: Embodied Carbon (2021) https://www.westofengland-ca.gov.uk/wp-content/uploads/2022/01/Spatial-Development-Strategy-Evidence-base-for-Net-Zero-Building-Policy-Embodied-Carbon-Jan-2022.pdf

# 3 METHODOLOGY

The methodology behind measuring and reporting greenhouse gas emissions from construction projects is evolving as the industry learns and adapts to the challenges of mitigating climate change. The methodology for assessing both carbon and cost information in this report has followed latest available industry guidance at the time of writing from:

- UK Green Building Council (UKGBC)
- Low Energy Transformation Initiative (LETI)
- Royal Institute of British Architects (RIBA)
- Royal Institute of Chartered Surveyors (RICS)
- Institute of Structural Engineers (IStructE)
- Centre for Window and Cladding Technology (CWCT)
- Chartered Institute of Building Services Engineering (CIBSE)

This document has focused on establishing the embodied carbon and cost of 3 typical building archetypes for The City of Westminster. It is based on a mixture of empirical data from previous WSP projects in London, along with material quantities developed from generated structural, MEP and Façade design information for each archetype.

## 3.1 BUILDING TYPOLOGIES

3 building typologies were explored for this exercise, two for non-domestic development and one for domestic, which were selected as 3 very common building typologies for the region:

- **Office**: 7 Storeys, Gross Internal Floor Area (GIA) 9,072 $m^2$
- **Mixed Use**: 7 Storeys, Gross Internal Floor Area (GIA) 9,072 $m^2$
- **Residential**: 8 Storeys, Gross Internal Floor Area (GIA) 6,912 $m^2$

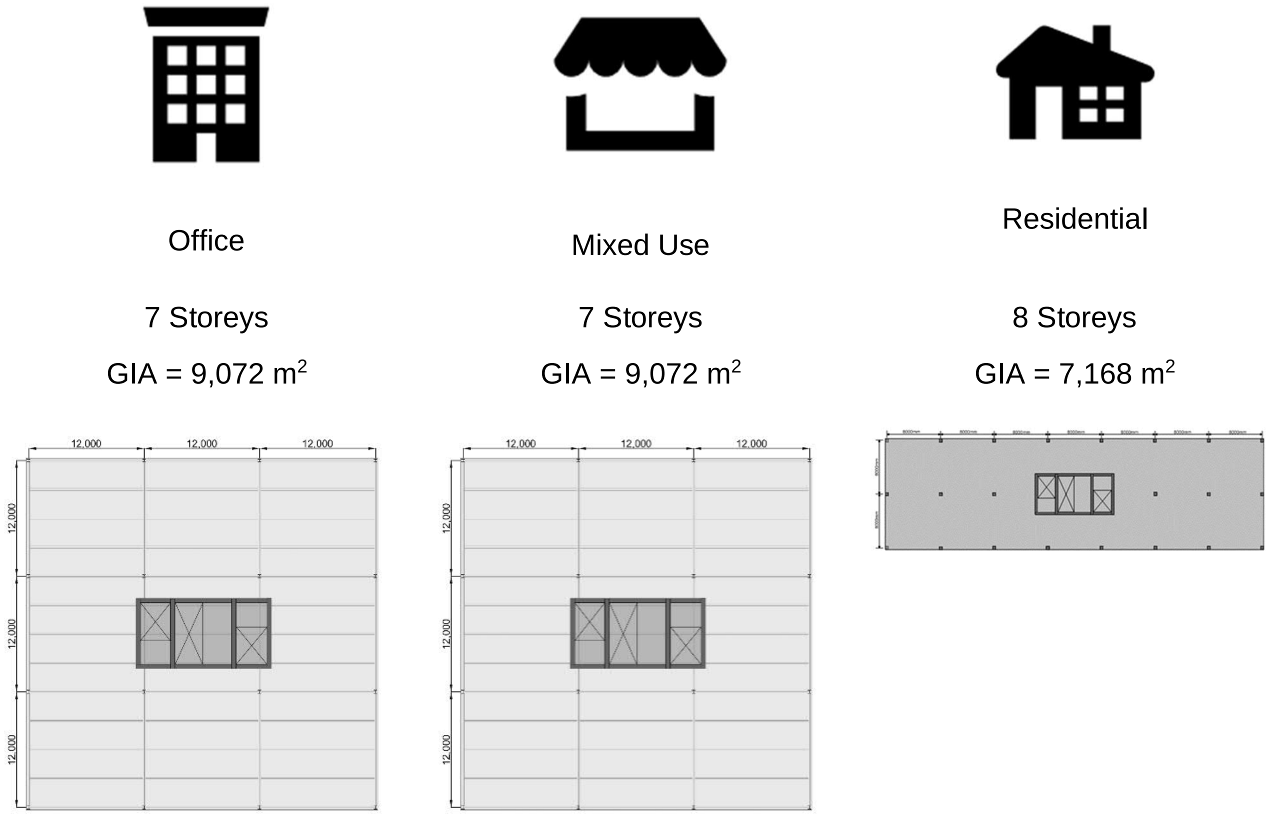



***Figure 3-1 – Building archetypes used in study, representative of typical mid-rise building buildings in the City of Westminster.***

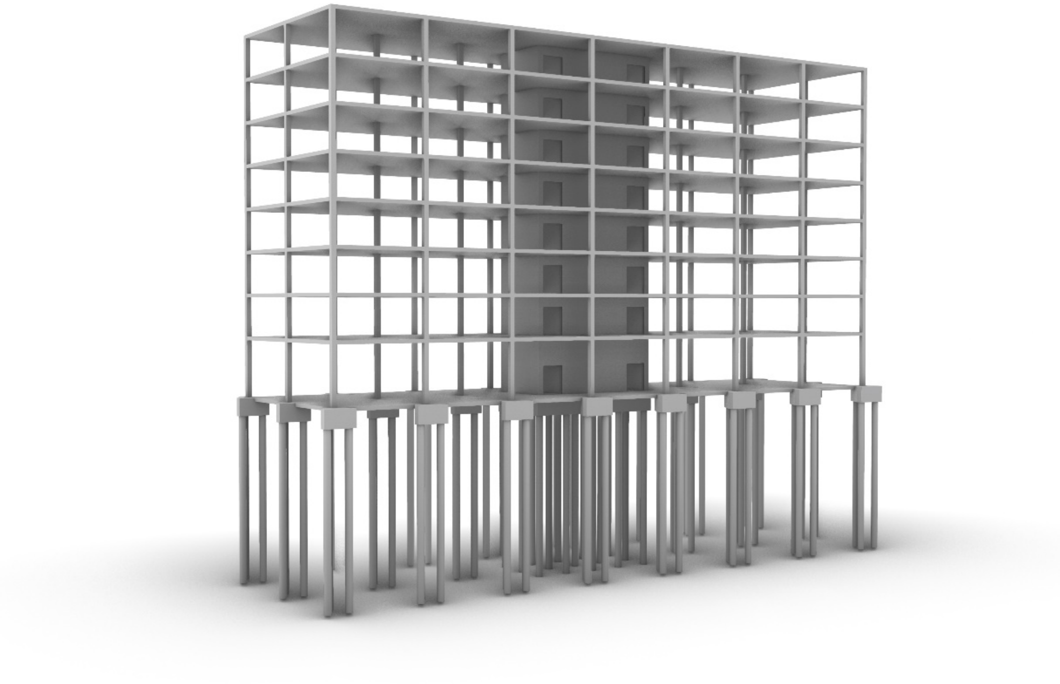


***Figure 3-2 – Residential archetype 3D view (structure only)***

***Figure 3-3 – Office & mixed-use archetype 3D view (structure only)***

## 3.2 BASELINE AND ALTERNATIVE SCENARIOS

3 different baselines were created for the study these are:

Office:

- Steel structural frame with composite concrete-steel deck slabs for floors
- Stick-system curtain walling with Double Glazed Unit and opaque external wall with terracotta finishing
- Heat pumps and chillers, with typical fan coil unit arrangement

Mixed Use:

- Steel structural frame with composite concrete-steel deck slabs for floors
- Stick-system curtain walling with Double Glazed Unit and opaque external wall with terracotta finishing
- Mix of residential and commercial MEP system

Residential:

- Concrete structural frame with flat concrete slabs for floors and roof
- Triple Glazed Unit aluminium window and opaque external wall with terracotta finishing
- Ambient loop system with secondary heat pumps in each apartment

Then, using the baselines, seven alternative scenarios were developed as summarised in Table 3-1 below:

*Table 3-1 – Alternative scenarios.*

| Building Archetype | S1 - Baseline | S2 – Reduced Grid Spacing | S3 – Low Carbon Concrete | S4 – Hybrid Timber |
|---|---|---|---|---|
| **Office** | Steel frame and composite concrete-steel deck floor slabs | Reduction in grid spacing from 12m to 9m. | +25% GGBS replacement added to concrete mixes | Steel frame and CLT floors/ roof |
| **Mixed-Use** | Steel frame and composite concrete-steel deck floor slabs | Reduction in grid spacing from 12m to 9m. | +25% GGBS replacement added to concrete mixes | Steel frame and CLT floors/ roof |
| **Residential** | Concrete frame and reinforced concrete in-situ flat slabs | Reduction in grid spacing from 8m to 6m. | +25% GGBS replacement added to concrete mixes | – |

| S5 – Low Carbon Steel<br>& 50% GGBS (Residential) | S6 – Glulam Beams and CLT Floors | S7 – Low Carbon Facade | S8 – Low Carbon MEP |
|---|---|---|---|
| +10% steel reuse & +15% EAF steel | Glulam beams and CLT floors / roof | Increase recycled aluminium content of the curtain walling framing and replace terracotta rainscreen cladding components with timber cladding. | Replace traditional 4-pipe fan coil unit HVAC system with displacement ventilation system with on floor air handling units. |
| +10% steel reuse & +15% EAF steel | Glulam beams and CLT floors / roof | Increase recycled aluminium content of the curtain walling framing and review external wall build-up including bricks as finishing. | Replace ambient loop system with heat pump in apartments with more typical LTHW heating only system. Commercial same as office baseline |
| +50% GGBS replacement added to concrete mixes | – | Replace window aluminium framing with composite framing and review external wall build-up including bricks as finishing. | Replace ambient loop system with heat pump in apartments with more typical LTHW heating only system. |

The scenarios described above were applied cumulatively to the baseline, such that the combined impact could be examined. This assessment allowed for the combined impact of these interventions to be explored and the results to be compared against current industry best targets with a view to informing any embodied carbon targets to be set by policy.

## 3.3 BUILDING ELEMENTS

To assess which building elements should be in-scope or out-of-scope, the guidelines from the Whole life carbon assessment for the built environment (2017) by RICS[2] have been reviewed and followed. According to these guidelines, the minimum requirements for a whole life carbon assessment in terms of building elements are the Substructure (RICS 1) and Superstructure (RICS 2) elements.

For the purpose of this study, the scope for the detailed analysis includes the Substructure (RICS 1), Superstructure (RICS 2) calculated following guidance from IStructE and CWCT and Building Services (RICS 5) elements following guidance from CIBSE. These were chosen as:

- They are expected to have a high share of embodied carbon emissions
- They are commonly considered during early design stages

However, in order to safely compare the results against the selected embodied carbon targets (such as RIBA), more elements should be accounted for so that the scopes are aligned. For this reason, after the modelling the substructure, superstructure and finish elements (as per detailed analysis scope) for the baseline, a percentage increase was added on the results to account for the fixtures and finishes (RICS 3) and the external works (RICS 8). The factors used for this percentage increase are based on GLA benchmark values, from the GLA's Guidance on Whole Life-Cycle Carbon Assessments. These have been applied as a percentage of the GLA Benchmark Value and then applied consistently to each option.

***Table 3-2 – Percentage increase per building typology for the Finishes FFE and the External works (extended scope).***

| | Finishes | FFE | External Works |
|---|---|---|---|
| **Office** | 10% | 2% | 2% |
| **Mixed Use** | 9% | 1% | 2% |
| **Residential** | 10% | 1% | 1% |

[2] RICS, 2017. Whole life carbon assessment for the build environment. Online Available at: https://www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf

Finally, there are some categories of building elements which were left out of the scope of this assessment as these will vary considerably depending on the unique nature of each project and would not be feasible to calculate for a generic archetypal building. These categories include the Facilitating works (RICS 0), Prefabricated buildings and building units (RICS 6) and the Works to existing building (RICS 7). Table 3-3 below summarises the in-scope and out-of-scope elements considered for this study.

***Table 3-3 – Building elements in scope of this assessment by RICS category.***

| **RICS(2017) Category** | | **Data Source** |
|---|---|---|
| 0.1 | Demolition: Toxic/Hazardous/Contaminated Material Treatment | Excluded |
| 0.2 | Major Demolition Works | Excluded |
| 0.3 | Temporary Support to Adjacent Structures | Excluded |
| 0.4 | Specialist Ground Works | Excluded |
| 1.0 | Substructure | ISTRUCTe Methodology |
| 2.1 | Superstructure: Frame | ISTRUCTe Methodology |
| 2.2 | Superstructure: Upper Floors | ISTRUCTe Methodology |
| 2.3 | Superstructure: Roof | ISTRUCTe Methodology |
| *2.4* | *Superstructure: Stairs and Ramps* | *Based on WSP LCA data* |
| 2.5 | Superstructure: External Walls | CWCT Methodology |
| 2.6 | Superstructure: Windows and External Doors | CWCT Methodology |
| *2.7* | *Superstructure: Internal Walls and Partitions* | *Based on WSP LCA data* |
| *2.8* | *Superstructure: Internal Doors* | *Based on WSP LCA data* |
| 3.0 | Finishes | GLA Benchmark |
| 4.0 | Fittings, furnishings & equipment (FFE) | GLA Benchmark |
| 5.0 | Services (MEP) | CIBSE TM65 Methodology |
| 6.0 | Prefabricated Buildings and Building Units | Excluded |
| 7.0 | Work to Existing Building | Excluded |
| 8.0 | External works | GLA Benchmark |

| | |
|---|---|
| (orange) | Structures ISTRUCTE Calculation |
| (light peach) | In structural scope based on WSP project LCA data |
| (blue) | Façade CWCT Calculation |
| (yellow) | Services CIBSE TM65 Calculation |
| (grey) | Based on GLA Benchmark |
| (white) | Excluded from calculation |

## 3.4 STRUCTURAL METHODOLOGY

The IStructE produced the guide "How to calculate embodied carbon (2nd edition)" for the structural engineering community to follow when calculating embodied carbon. The guide establishes a baseline for calculating embodied carbon such that all designs can be compared between structural schemes. To quantify the structural embodied carbon as per the IStructE guide, the quantity of each material is multiplied by a carbon factor for the life cycle modules being considered (see Equation 1 below). Each structural element for the study in Westminster has been calculated using the methodology as described above and in the IStructE guide.

| |
|---|
| Material quantity (kg) x carbon factor (kgCO2e/kg) = embodied carbon (kgCO2e) |

In order to derive material quantities for each of the options, full structural schemes were developed which assessed beam & slab sizes/thicknesses, column sizes, outline sizes for stability members and optimal foundation types and sizes (explained further in Section 3.4.1). From this, accurate material quantities, and subsequently embodied carbon, could be calculated.

### 3.4.1 GEOTECHNICAL & FOUNDATIONS

Foundations are a large structural contributor of embodied carbon and as such it formed an important area of focus for this study. We engaged with our geotechnical team to understand the expected ground conditions within Westminster and therefore likely foundation solutions for our designs.

Whilst the buildings are of no fixed position, the likely strata to be encountered within the borough of Westminster can be loosely divided into two zones. Close to the river in the South, there is an approximate 7m of made ground overlaying alluvium, sand, gravel, then London clay. In the North of the borough, the depth of made ground reduces to approximately 3m. The soil data in the North of the site has formed the basis of the foundation design undertaken herein as it represents the largest area within the borough itself and is therefore deemed more representative of a typical building.

Based on the assessed foundation loads for each building, pile-load graphs were used to determine the required pile depths & diameters for both the piled wall (where a basement was present) and for piles beneath pile caps.

### 3.4.2 SEQUESTRATION

In order to account for the benefit of sequestration within a whole-life carbon calculation, it must be ensured the sequestration will happen; the timber must be sustainably sourced, and the felled trees must be replaced in line with current European standards. Therefore, on a typical project, whether or not to include sequestration and how to incorporate the figures within carbon calculations will come down to project specifics relating to how the timber has been procured.

Because these procurement requirements cannot necessarily be guaranteed, for this study the biogenic carbon numbers are not included within the results, and it can be decided on a project-by-project basis whether or not to include them subject to aforementioned procurement requirements.

## 3.5 FAÇADE METHODOLOGY

In September 2022, the CWCT introduced a methodology titled "How to calculate the embodied carbon of facades". This method aims to establish consistency in the industry when determining the embodied carbon of facades. The CWCT methodology, part of a suite of guides for various building elements like the primary structure (IStructE guide) and building services (CIBSE TM65), underscores the significance of a meticulous evaluation of individual building facade components. The assessment, tailored to the design stage, involves a conceptual estimation of embodied carbon, considering allowances for uncertainties, variations, and contingencies.

During the early design phases the assessment is conceptual, estimating the embodied carbon and other relevant characteristics of the facade system whilst including allowances for uncertainty. These allowances address variations in the carbon footprint of the construction of a façade system and ensure more realistic estimates. The primary objective is to derive accurate figures for the embodied carbon and other aspects of the facade through a detailed assessment of its components and materials. Once these figures are established, they can be included in project documentation providing clear specifications for sustainability, materials, and other factors to contractors.

The CWCT Methodology follows the framework set out in BS EN 15978 and is aligned with the RICS Professional Statement: “Whole Life Carbon assessment for the build environment”. Within the RICS guidance, the façade is to be considered within the “Superstructure” building element group in whole life carbon assessments. More specifically this includes the building elements 2.5 External Walls and 2.6 Window and External Doors within this group listed in Table 3 within the RICS guidance.

### 3.5.1 FAÇADE FORM FACTOR

The usual method for calculating the embodied carbon of a facade involves expressing it in units per square meter of facade surface area (FSA). This stands in contrast to typical building carbon targets or assessments, which are often presented in units per square meter of gross internal floor area (GIA). Consequently, the ratio between a building's FSA and GIA, referred to as the 'Facade Form Factor (FFF),' plays a crucial role in determining the facade's impact on the overall embodied carbon of the building.

The FFF greatly influences how much the facade contributes to the overall embodied carbon per square meter of GIA. Buildings with low form factors, meaning more efficient designs, will have facades that contribute less to the building's total embodied carbon.

**Table 3-4 – Façade surface area and form factor for each building archetype.**

| Building Archetype | GIA | FSA | FFF |
|---|---|---|---|
| Mixed Use | 9072 | 4248 | 0.47 |
| Office | 9072 | 4248 | 0.47 |
| Residential | 7200 | 7168 | 1.00 |

### 3.5.2 WINDOW-TO-WALL RATIO

The Window to Wall Ratio (WWR) is the proportion of a facade's surface area that is occupied by windows, and it is a critical parameter for embodied carbon calculations as it affects the choice of materials, energy use during the building's lifespan, manufacturing processes, transportation emissions, and end-of-life considerations.

Understanding and optimising the WWR is essential for designing facades that align with sustainability goals and minimise the overall environmental impact of a building: a higher window-to-wall ratio increases solar heat gains and consequently cooling demands, but also allows for more natural light, reducing the need for additional light fixtures. Nevertheless, the WWR is a project specific parameter to be optimized also in accordance with climate, building orientation and intended use.

Different transparent areas have been assigned to the archetypes in accordance with the defined building geometry. For residential, the maximum area of glazing has been defined in accordance with the Building Regulations, Approved Document Part O – Overheating.

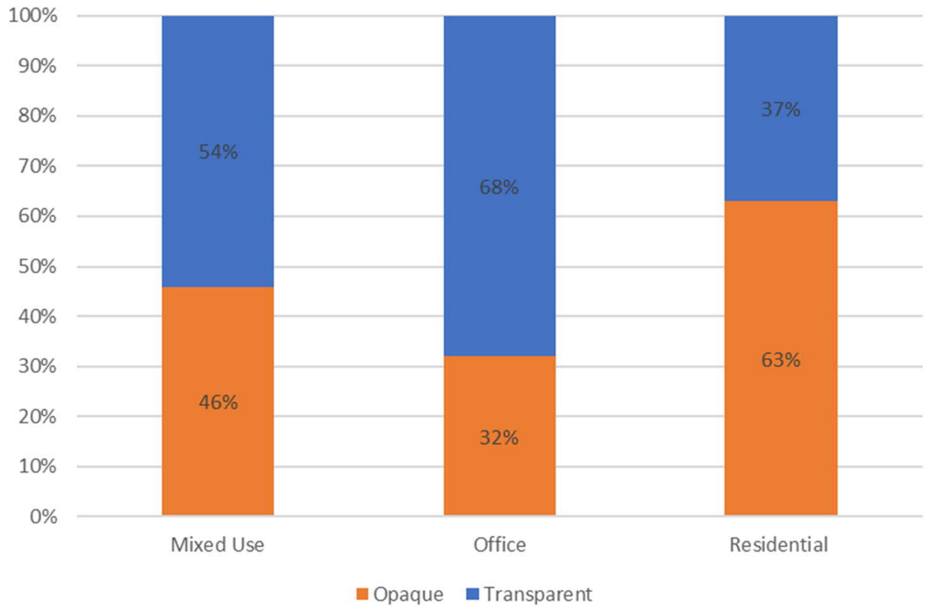



***Figure 3-4 – Window to wall ratio of each building archetype.***

### 3.5.3 FAÇADE SYSTEMS

Two different scenarios have been used to define façade systems of each building archetype. A transparent and an opaque build-up are used in the proportions explained above. A baseline has been defined for the typical façade systems and an optimised alternative has been produced to compare the two scenarios.

Some components have been substituted for lower carbon intensive solutions. Their procurement strategy has been revised to accommodate for materials that are manufactured locally or nationally (RICS defines different transport scenarios when components are transported by an average rigid

HGV with average laden for 50 km or 300 km by road). Furthermore, a reduced wastage rate has been applied (based on the standard wastage rates provided by the WRAP net waste tool).

Some other strategies can be adopted such as Designing for Disassembly (DfD) to promote the circular economy principles of reusing, recycling and upcycling components at the end of their life, and design for extreme climate conditions adaptation, but it is not straightforward to quantify the reduction in terms of embodied carbon.

### 3.5.4 FURTHER OPTIMISATION

In the hypothesis that the current scenario will evolve, and the timber cladding assembly is not discarded as an option for residential buildings, a further optimisation has been used to compare the above-mentioned options with a more sustainable façade system.

Following the same approach, and supposing that the content of recycled glass will increase in the glass production, an alternative for offices has been included.

***Table 3-5 – Façade embodied carbon reduction measures and materials assessed.***

| Building Archetypes | Typical Facade Systems | Low Carbon Façade Systems | Further Optimisation |
|---|---|---|---|
| Office | Aluminium framing curtain walling system<br>+ Rainscreen terracotta* cladding | Curtain walling with higher recycle content in aluminium framing<br>+ Rainscreen timber cladding | Same as per Low Carbon Façade System but with recycled glass |
| Residential | Aluminium framing window<br>+ Rainscreen terracotta* cladding | Composite framing window<br>+ Steel Framing System and brick finishing | Same as per Low Carbon Façade System but with timber cladding assembly |
| Mixed Use | Mixed (45% Office, 45% Residential, 10% Retail) | Mixed (45% Office, 45% Residential, 10% Retail) | Same as per Low Carbon Façade System but with timber cladding assembly |

*Terracotta cladding has been selected to allow for different cladding materials that are high contributors in terms of embodied carbon. A relatively heavy rainscreen panel also needs a substructure (usually made of metals) to be installed.

The figure below summarises the embodied carbon content (kg$CO_2$e/m$^2$GIA) for each option compared with the LETI targets for facades.

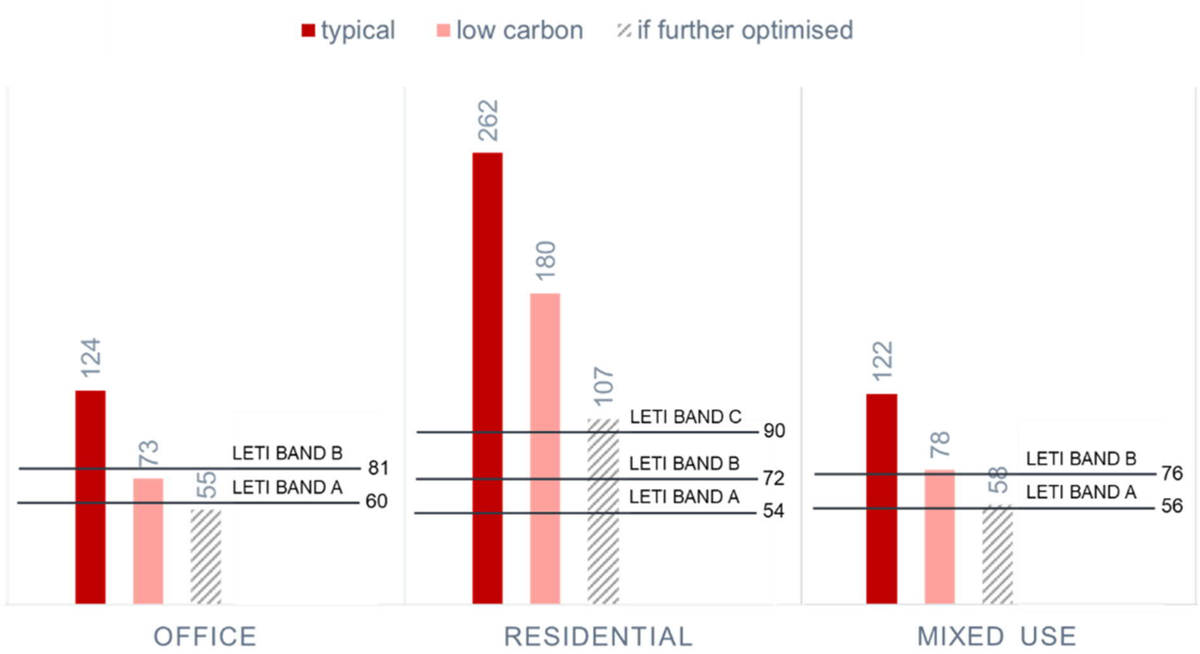



***Figure 3-5 – Embodied carbon of each façade system assessed compared to LETI upfront embodied carbon targets.***

## 3.6 SERVICES METHODOLOGY

### 3.6.1 INTRODUCTION

In response to growing concern about the amount of embodied carbon in building services products, in January 2021 CIBSE introduced the TM65 document to guide professionals in quantifying and understanding the embodied carbon associated with building services equipment. The document outlines an approach to measuring embodied carbon for a building services product lifecycle, from material extraction, manufacturing, and transport to the end-of-life processes, such as waste processing and disposal. Furthermore, TM65 accounts for complexities in product manufacturing and provides recommendations for carbon estimations in the absence of specific data, ensuring a comprehensive, yet adaptable methodology for various building services products.

The amount of data on embodied carbon of building services equipment (namely Environmental Product Declarations or CIBSE TM65 Forms) is limited and constantly evolving as the industry adapts to this new challenge. TM65 accounts for this by applying a product complexity factor, and conservative buffer factor to account for uncertainty in carbon data and to provide an element of contingency to the calculations.

### 3.6.2 OVERVIEW

The embodied carbon calculation for RICS category 5 has been undertaken using the WSP MEP Embodied Carbon Calculator. Two scenarios have been assessed for each option: a base-line MEP system, and then a low carbon option. The only difference between the options is the HVAC design, with all other services such as power supply, fire suppression, vertical transport and drainage remaining constant between the options. The analysis has only considered the upfront A1-A5 embodied carbon emissions of the system, and the operational energy and carbon emissions of the building have not been considered in this analysis. The 'low carbon' option is therefore a low embodied carbon option and in some cases there may be a trade-off against increased operational emissions. In the case of the residential, the capacity to provide cooling to the apartments is removed, reducing carbon and cost however increasing the probability of that apartment overheating during summer months impacting occupant comfort. However, this system has been chosen as it is still uncommon for most buildings in the UK to be fitted with air conditioning, and overheating risk can be addressed through improving solar control at the design stage. The high-level description of MEP services options used in the assessment can be found in Table 3-6.

*Table 3-6 – MEP services options.*

| Building Archetypes | Baseline | Low Carbon |
| --- | --- | --- |
| Office  | Typical fan coil unit supplied by air source heat pumps and chillers | Displacement underfloor air distribution system supplied by on floor air handling units, air source heat pumps and chillers |
| Residential  | Ambient loop system supplied by air source heat pumps and chillers with heat pumps in each apartment | Central heating system with central air source heat pumps with underfloor heating in each apartment. |
| Mixed Use  | Office Baseline + Residential Baseline | Office Baseline + Residential Low Carbon |

The MEP design information for each building archetype has been taken from WSP projects in London which closely matched the building archetypes. These have then been scaled pro-rata based on the floor area to match the size of the building archetypes. The mixed-use archetype has been made up of a combination of the residential units assuming the baseline commercial system for the office and retail units.

Information on mechanical and electrical plant items (for example, heat pumps, air handling units, transformers etc.) have been taken from RIBA Stage 4 detailed design schedules for each project. For distribution systems (pipes, ducts, cables etc.) an area weighted value for a typical pipe or duct system has been used, based of typical carbon factors from OneClickLCA.

### 3.6.3 WSP MEP EMBODIED CARBON CALCULATOR

The WSP MEP Embodied Carbon Calculator has been developed in accordance with guidance from CIBSE (CIBSE TM65). For Building Services Plant, it uses the plant schedule including the number and predicted weight of each component. If EPD data can be found for the product type, then the calculator uses this for the calculation. If no EPD data can be found for the product then the calculation follows the CIBSE TM65 Basic methodology, which involves estimating the material breakdown of the product and then applying the relevant carbon factor based on the ICE materials database, with appropriate scale up factors to account for the complexity of the supply chain of the product.

## 3.7 LIFECYCLE STAGES

To determine the lifecycle stages to be included in the scope of this study, new LETI guidance 'Embodied Carbon Target Alignment' (2021) and the guidelines from the "Whole Life Carbon Assessment for the Built Environment" (2017) by RICS[3] have been reviewed. As a result, two lifecycle stages scopes were followed.

This analysis has only considered A1-A5 upfront emissions. This is a limitation of this assessment, and the results should only be compared to upfront embodied carbon targets. However, upfront emissions, from a regulatory perspective, are the most impactful and are important to limit as they are the emissions emitted by the developer during construction up until practical completion, where the building usually changes hands. Setting ambitious upfront embodied targets for new construction should have the effect of encouraging more redevelopment of existing buildings. However, this should always be accompanied by a whole life carbon study to prevent short term decision making and promote designs with a long life and low operational carbon emissions.

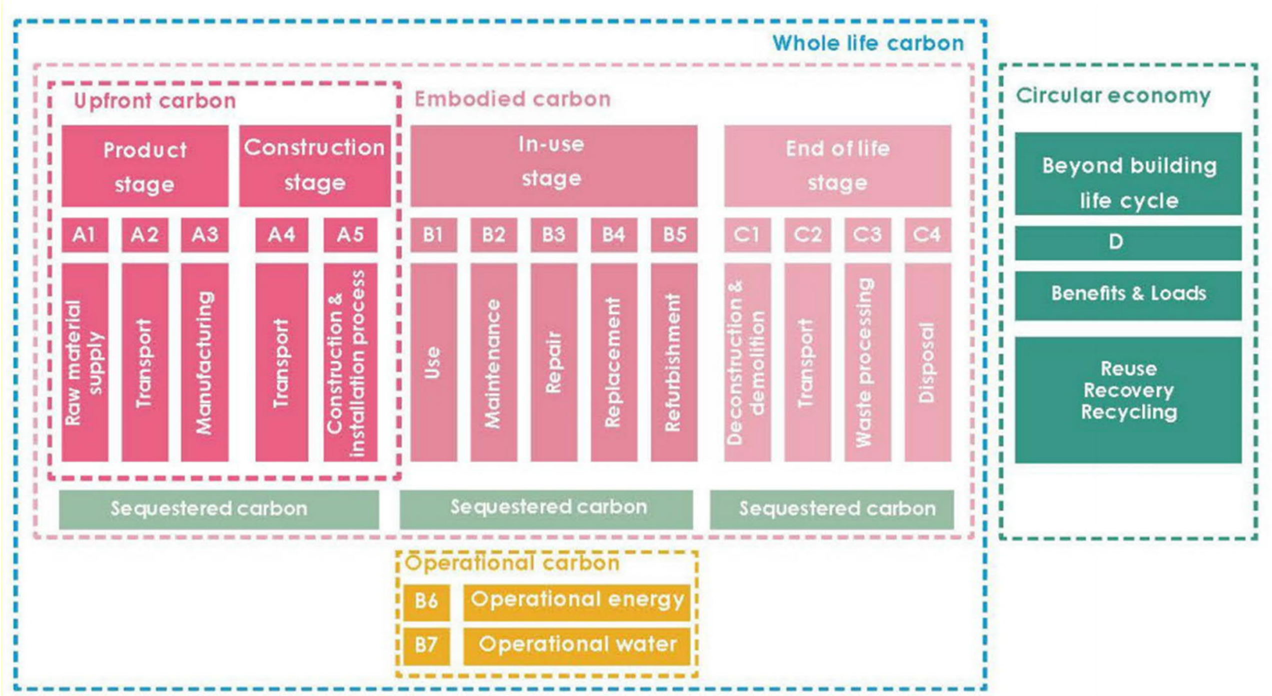



***Figure 3-6 – Life cycle stages as defined by BS EN 15978:2011, Diagram by LETI.***

[3] RICS, 2017. Whole life carbon assessment for the build environment. Online Available at: https://www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf

- **In the Scope of this Assessment – Upfront Embodied Carbon**: This scope focuses only on the upfront carbon (A1-A5)
- **Out of Scope of this Assessment – Whole Life Embodied Carbon**: This scope focuses on the upfront carbon (A1-A5), the carbon from future replacements with the same material (B4) and the end-of-life carbon (C1-C4). It should be highlighted that the stages B1-Use, B2-Maintenance and B3- Repair have been excluded from the scope due to limited data and their relatively small impact in comparison with the rest of the lifecycle stages. Moreover, the stage B5-Refurbishment, which focuses on replacements with different materials, hasn't been considered as it depends on highly unpredictable parameters such as change of function, aesthetic preferences, technological outdate etc.

Module D and carbon sequestration have been excluded from both scopes for the purpose of this assessment, but it is recommended that these carbon 'benefits' are asked to be reported separately by the new policy.

## 3.8 COST ASSESSMENT METHODOLOGY

WSP quantity surveying team have undertaken a cost analysis of the scenarios presented within this report. The study analyses the capital cost for each building type and embodied carbon scenario and is intended to inform policy.

The analysis is split into the 3 building types and multiple different embodied carbon scenarios outlined within this report; please refer to Section 3.1 for details.

The building elements and quantities for each scenario have been produced by WSP based on design information for each building archetype. The material and quantity outputs were then reviewed and advised on their relevance in reference to current practice based on construction experience. Examples include the appropriate rate for a timber clad façade system. It should be noted that these scenarios are hypothetical only, and on a real-life project they would benefit from a further design assurance, design validity or buildability assessment as part of the next design stage.

Once the final schedule of quantities was agreed, this was then developed into a cost plan format in order to accurately assess the cost of each scenario. The original set of quantities were broken down into individual materials before being grouped together to price composite rates. The building fabric elements were priced in detail based on benchmark rates and in consultation with the industry supply chain for key building elements such as terracotta tiling, structural steel, timber, reinforced concrete, and aluminium framing, costs were regionally specific to London and the City of Westminster.

The cost analysis results are shown within Section 4.2 below as a percentage variance from the baseline for each alternative scenario. This is not cumulative and should be read with reference to the change from the baseline.

The RICS categories costed for follow the same method of inclusion and exclusion as the embodied carbon calculation, as shown by Table 3-3, and therefore costs for demolition, enabling and specialist works have been excluded. Costs that could not be grounded in material quantities, i.e. fixtures, fittings and external works have been based on reference projects within London and/or the City of Westminster for that given archetype, and are fixed for each option.

This report provides an analysis of various carbon intervention measures aimed at reducing the embodied carbon of building materials. It is important to note that the cost estimates presented are subject to fluctuations due to a variety of external factors. These include global supply chain disruptions, such as those experienced during the COVID-19 pandemic, which can impact material availability and pricing. The effects of Brexit, including changes in trade regulations and customs procedures, has also significantly influenced the cost and availability of construction materials in the UK. The prices of raw materials, which are prone to global market changes, energy costs, and geopolitical events, further contribute to cost volatility. Environmental regulations and sustainability trends, aiming to reduce the carbon footprint, can also lead to higher costs for eco-friendly materials. We have seen the impact of this in the price of ecological cement replacements such as GGBS. Therefore, while this report strives to provide accurate and current data, the dynamic nature of these factors should be considered when interpreting the findings.

# 4 RESULTS AND DISCUSSION

## 4.1 POLICY THRESHOLDS

### 4.1.1 LEGISLATORY FRAMEWORK

On the 20th of April 2021, UK government announced a new law-binding target to reduce emissions by 78% compared to the 1990 levels by 2035[4]. This target comes as an interim target to the target of reducing emissions by 68% by 2030 and the net zero carbon target by 2050.

### 4.1.2 STANDARDS AND GUIDANCE REVIEW

The standards and guidance for embodied carbon were reviewed in order to understand what embodied carbon targets are recommended for domestic and non-domestic developments on their pathway towards net zero carbon, along the lifecycle stage scopes of these targets. Such targets are set in the documents below:

- RIBA 2030 Climate Challenge: The scope of these targets covers the whole life of a building (A-B-C), as defined by RICS[5]. In reality, not enough data exists today to address all these stages in a reliable way.
- LETI (London Energy Transformation Initiative) Climate Emergency Design Guide (the LETI targets are also followed by the work of UKGBC in their 'Building the Case for Net Zero' report).

***Table 4-1*** below summarises the RIBA and LETI targets.

[4] Press release: UK enshrines new target in law to slash emissions by 78% by 2035 (2021) https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
[5] A limitation on this comparison is that the current scope only doesn't include stages B1, B2, B3 and B5, while the RIBA 2030 Climate Challenge target includes them. This would be likely to have a very minor effect on the results.

***Table 4-1 – Embodied carbon targets according to the RIBA 2030 Climate Challenge and LETI (London Energy Transformation Initiative) Climate Emergency Design Guide.***

| | RIBA 2030 Climate Challenge (A, B, C life stages) | | | |
|---|---|---|---|---|
| Embodied Carbon ($kgCO_2/m^2$) | Current Benchmarks | 2020 Target | 2025 Target | 2030 Target |
| Domestic | <1000 | <600 | <450 | <300 |
| Non-Domestic | <1100 | <800 | <650 | <500 |

| | LETI Climate Emergency Design Guide / UKGBC ("A" life stage-upfront only) | | | |
|---|---|---|---|---|
| Embodied Carbon ($kgCO_2/m^2$) | Current Benchmarks | 2020 Best Practice | 2025 | 2030 Best Practice |
| Domestic | <800 | <500 | - | <300 |
| Non-Domestic | <1000 | <600 | - | <350 |

At the end of May 2021, RIBA and LETI published their 'Embodied Carbon Target Alignment' work[6], which aims to produce a standardised performance and reporting scope for embodied carbon assessments. This document therefore provides an alignment of embodied carbon measurement and benchmarking among RIBA, GLA, Institution of Structural Engineers and UKGBC. This publication introduces a rating system which allowed quick comparison of ambition across various typologies and portfolios and brings together the previous RIBA and LETI targets (mentioned above), as shown by ***Figure 4-1*** and ***Table 4-1***.

- The embodied carbon targets are shaped in letter bandings, rather than a single value target. The industry is already familiar with the letter rating system, as it has been used in the context of Display Energy Certificates.
- Targets are set for four typologies: Residential, Office, School and Retail

[6] 'Embodied Carbon Target Alignment' report. Online Available at: https://b80d7a04-1c28-45e2-b904-e0715cface93.filesusr.com/ugd/252d09_89cf50315c884fa796fdf07d1428b2e6.pdf

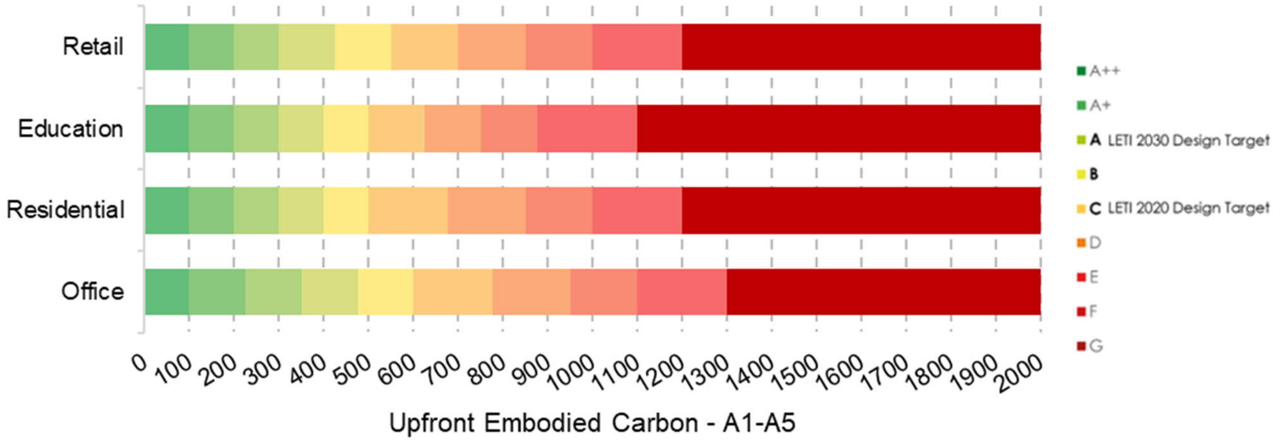



***Figure 4-1 – 'Embodied Carbon Target Alignment' - letter bandings.***

As part of this work, LETI and RIBA have aligned the new letter banding system with their previous targets. More specifically, the LETI position is that for buildings that are currently in the **design** stage:

- Average design achieves an E
- Good design achieves a C (LETI 2020 target)
- LETI 2030 design target achieves an A

The bandings do not currently differentiate between new build or refurbishment. Part of the rationale for this is that refurbishment projects will find it easier to achieve good performances and this provides an incentive for retrofit. It is expected that as more data is collected for ranges of retrofit, the bandings could be adapted if necessary.

### 4.1.3 SHORT TERM AND LONG-TERM POLICY THRESHOLDS

According to the 'Embodied Carbon Target Alignment' work, the current average practice in terms of embodied carbon performance is considered to be E, while the current best-practice performance is considered to be a C rating. Ratings from B and above are considered robust stretch targets.

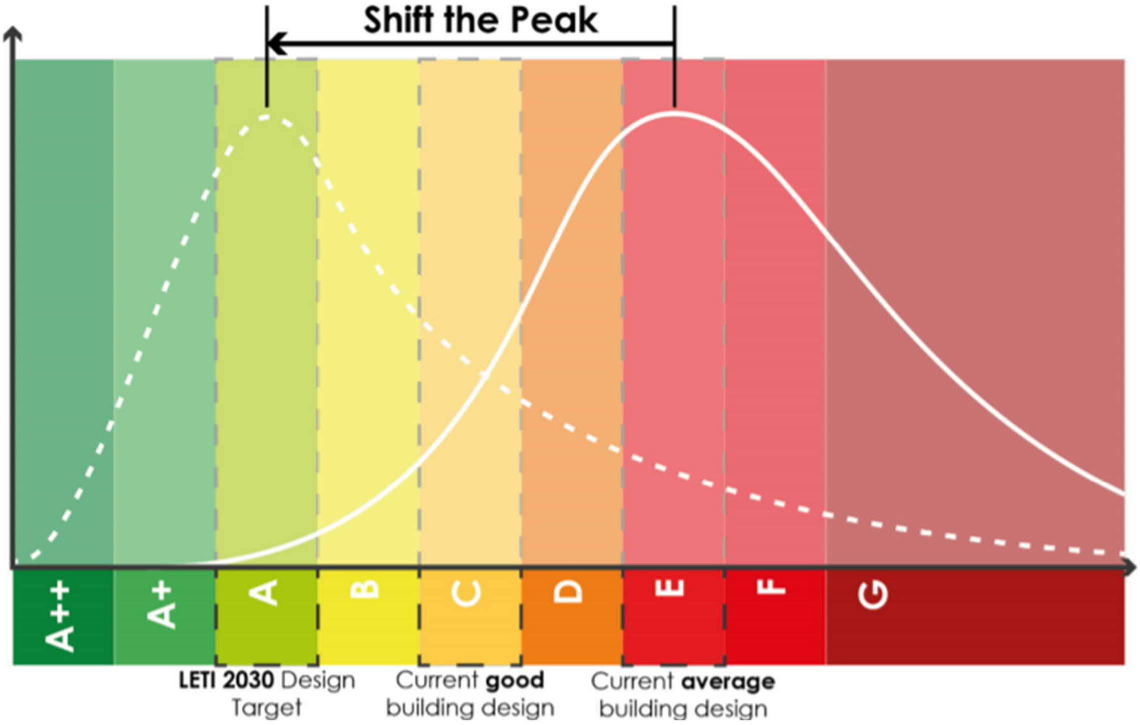
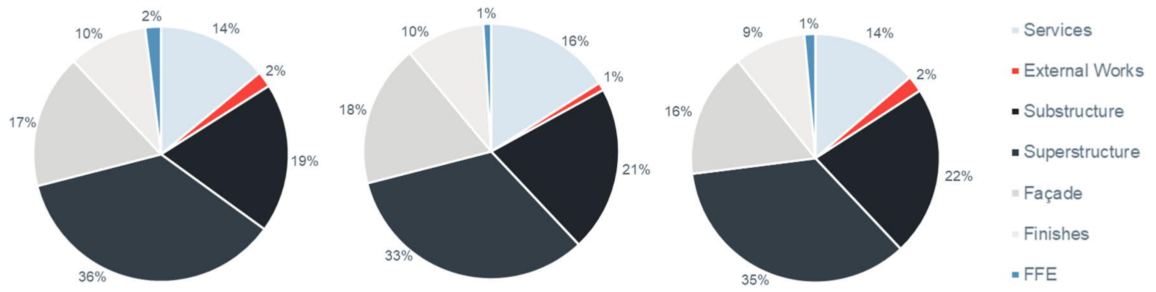



***Figure 4-2 – 'Embodied Carbon Target Alignment' - letter bandings with current average practice (E) and good practice (C).***

## 4.2 COST AND CARBON RESULTS

### 4.2.1 BASELINE

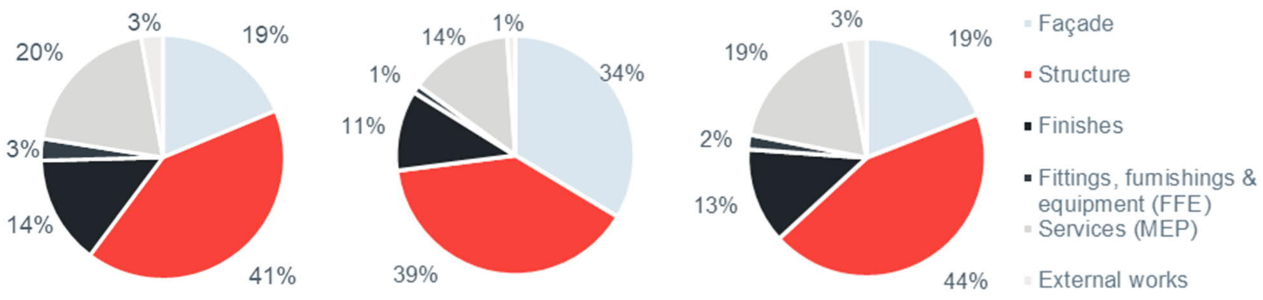
An initial analysis of the baseline embodied carbon scenario was undertaken to identify "carbon hotspots" - the building elements containing the most embodied carbon in buildings delivered through current industry practice. Figure 4-4 shows the upfront carbon share for the main building elements for the four building typologies (A1-A5). The structure (including substructure) can be seen to be the largest proportion of carbon emissions across all the archetypes at around ~40% of building emissions.




*A) Office* *B) Residential* *C) Mixed Use*

***Figure 4-3 – Carbon breakdown based on LETI guidance per building archetype.***

However, compared to industry benchmarks the embodied carbon for building services components and façade systems is proportionally higher than for example the approximate breakdowns given by LETI in their Climate Emergency Design Guide (2020), shown by Figure 4-3. This analysis draws on the most recent guidelines from the CWCT and CIBSE regarding the measurement of embodied carbon in façade systems and building services. This research has revealed that the environmental impact of products used in these construction areas is generally greater than previously estimated, reflecting an advancement in our understanding of these products. This is particularly the case for the residential archetype, where the facade can be seen to make up 34% of the baseline emissions. The increase is most pronounced in this archetype due to the high building surface area to volume ratio or form factor, leading to proportionally more façade per square metre of floor area.




*A) Office* *B) Residential* *C) Mixed Use*

***Figure 4-4 – Carbon breakdown of archetype baseline by engineering or architectural discipline.***

To calibrate the baseline value and put it in the context of wider LCA assessments, the overall upfront embodied carbon has been compared to data from 12 WSP LCA Assessments undertaken in London over the last 3 years. This helps position the embodied carbon of the building archetypes in the context of wider developments being undertaken in London. Figure 4-5 shows that each building archetype is above the median value but still within the range seen across WSP projects. The office and mixed-use baselines both achieving a D rating (or slightly better than industry average) and then the residential baseline achieving an E rating (or average design practice). Again, this higher figure is due in part to the low form factor selected for the residential building and the increase in façade contribution to the overall embodied carbon footprint since the development of the CWCT methodology.

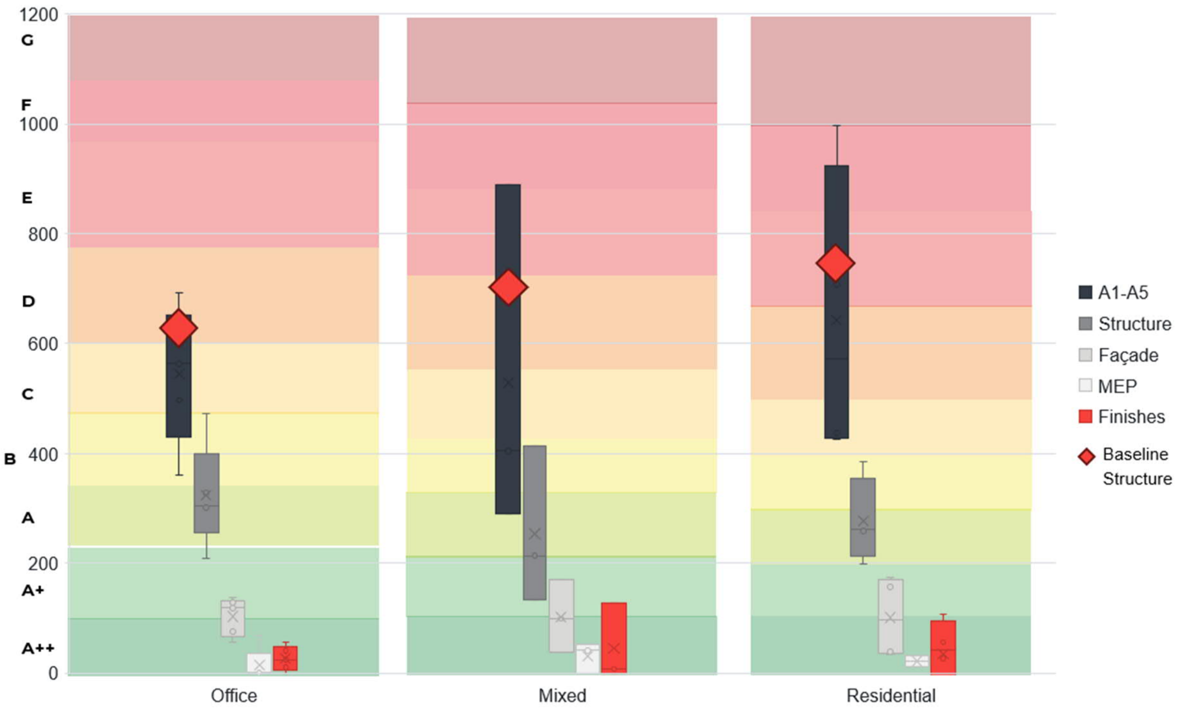



***Figure 4-5 – Comparison of baseline to benchmark and WSP LCA data.***

## 4.2.2 OFFICE

### Structure

The impact of applying each of the structural scenarios in sequence from the baseline are shown in Figure 4-6 below. The embodied carbon values shown are for structure only.

The impact of each scenario can be described as follows:

- Starting from the baseline, reducing the grid spacing from 12m to 9m results in a decrease in embodied carbon of 4% (-11kg$CO2_e$/$m^2$). This is an important step as it is independent of material specifications and can greatly reduce the embodied carbon given its impact on floor plate efficiency. When looking at overall structural contributors to embodied carbon, the floor plates are usually the most carbon intensive, and so targeting the spans can have a significant impact on overall embodied carbon.

- Introducing 25% cement replacement results in a further reduction of 7% (-19kg$CO2_e$/$m^2$). It should be noted that the baseline contained 0% cement replacement, as we suggest that measures to reduce carbon which are not reliant upon material specifications (e.g. reducing grid spacings) should be explored first. This is because any subsequent specification changes will have an overall greater impact without reliance upon specific material procurement routes.
- Replacing the composite decking with CLT flooring has a large reduction from the previous scenario of 21% (-52kg$CO2_e$/$m^2$). As previously stated, the floor plates are typically the largest structural contributor to embodied carbon and this is exemplified by the significant change here. Should certain timber procurement routes be met (as described in Section 3.4.2) then further benefit to the whole life carbon could be obtained through sequestration.
- Adopting low carbon steel provides a further reduction of 12% (-23kg$CO2_e$/$m^2$) against the previous option. In this context, an additional 15% EAF steel and 10% steel reuse has been considered relative to the previous steel specification - this is deemed to be a reasonable and realistic assumption based on available procurement in the current market.
- Adding more timber to the structure in the form of a glulam frame sees another large reduction in carbon of 10% (-17kg$CO2_e$/$m^2$).

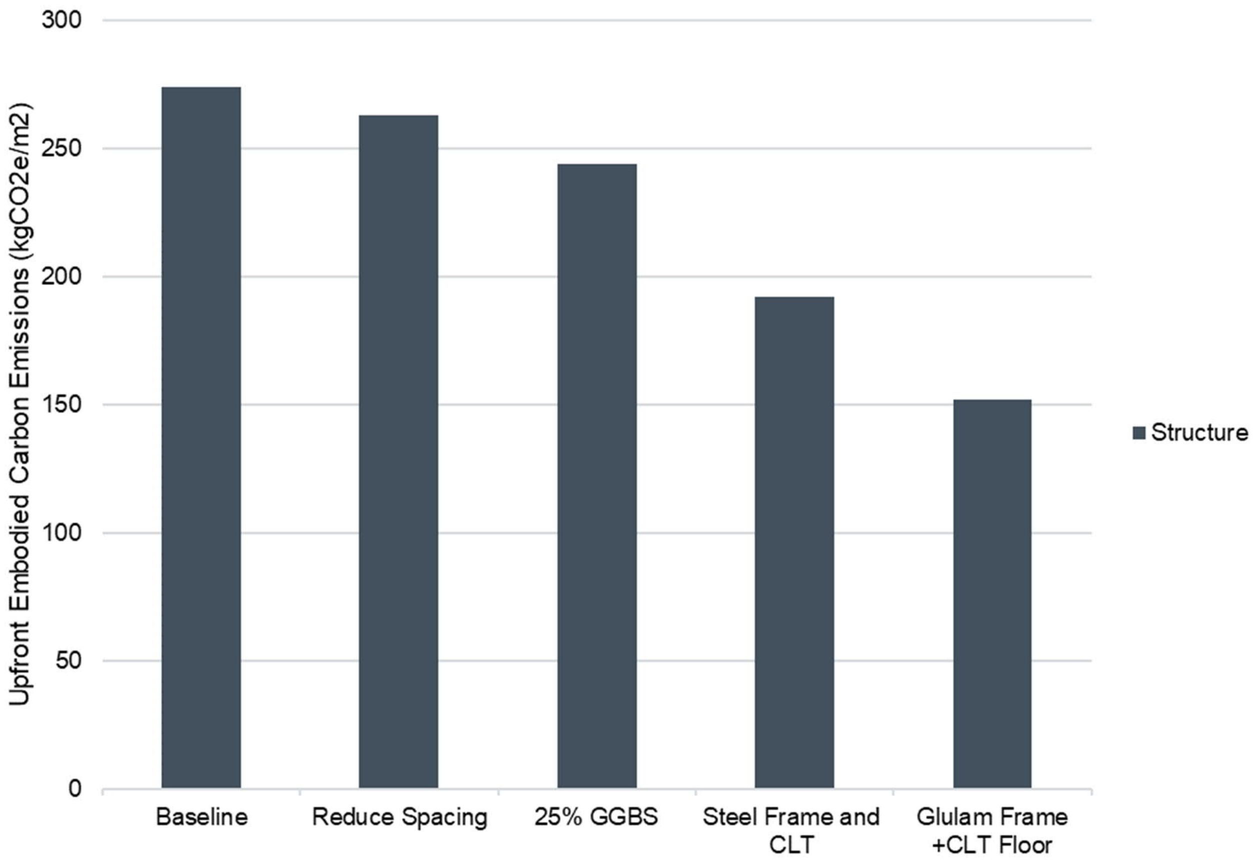



***Figure 4-6 – Impact of structure on carbon emissions.***

## Façade

The façade embodied carbon reduction for offices is related to the substitution of some components within the façade build-up which are commonly used for rainscreen but are heavy contributors in embodied carbon.

For this exercise, the terracotta rainscreen panel (and its metal substructure) has been included in the baseline to allow for common finishings, while the optimised system includes low-carbon materials such as timber rainscreen cladding.

The transparent façade is made of a curtain walling system where aluminium components are responsible for almost 60% of the embodied carbon of the facade system. In the optimised option the content of recycled aluminium has been increased from around 30% to 75%.

Even though the cost associated to opaque rainscreen is reduced due to the inclusion of low-carbon components, the low carbon façade sees an overall cost increase due to the cost associated with recycled aluminium in the glazing system.

- Adopting a greater proportion of recycled aluminium into the framing system and using a timber rainscreen cladding could lead to a reduction of façade embodied carbon of up to 41% (-51 $kgCO2_e/m^2$).
- Incorporating more recycled glass could lead to a further reduction of 15% (-18$kgCO2_e/m^2$) noting that recycled glazing units are not currently widely available from the market.

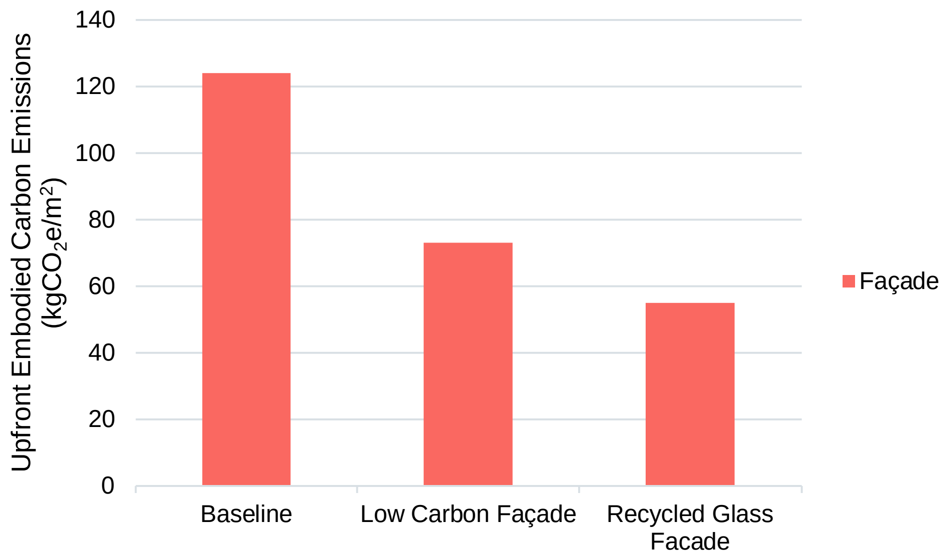



***Figure 4-7 – Impact of facade on carbon emissions.***

## Services

For the low carbon scenario for the office MEP, the heating, ventilation, and air conditioning (HVAC) system was changed from a typical fan-coil unit system to a displacement ventilation system with underfloor air distribution. This reduced the overall embodied carbon of the system by removing much of the on-floor distribution, including fan-coil units, pipework and ductwork and the resultant aluminium suspended ceiling grid.

- optimising the heating, ventilation, and air conditioning (HVAC) system, and shifting towards an underfloor air distribution system can save up to 31% (-40 $kgCO2_e/m^2$) of the embodied carbon emissions of the system.

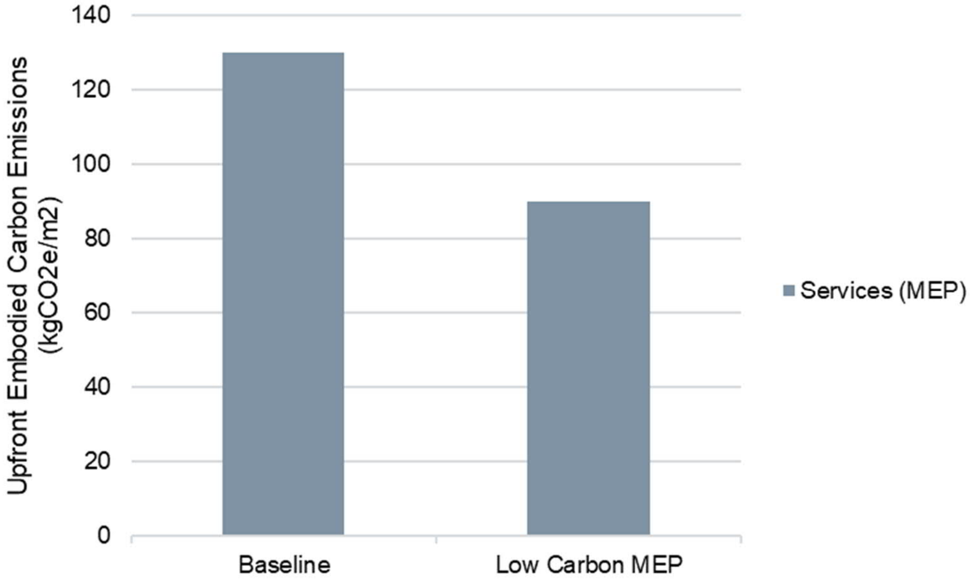



***Figure 4-8 – Impact of services on carbon emissions.***

**Carbon Reduction When Combined**

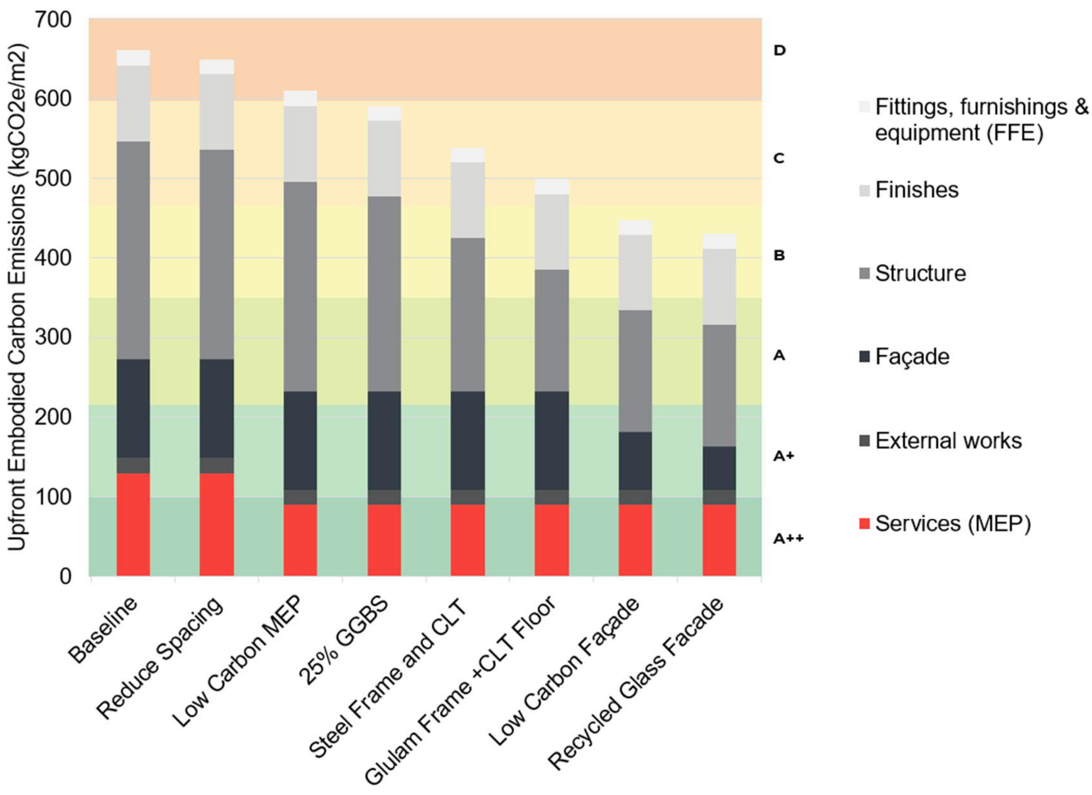



***Figure 4-9 – Carbon and cost impact of intervention when considered in combination.***

**Cost Impact**

**Table 4-2 – Cost impact of each intervention for office.**

| RICS (2017) Category | | Baseline | Reduce Spacing | Low Carbon MEP | 25% GGBS | Steel Frame and CLT | CLT Frame | Low Carbon Façade |
|---|---|---|---|---|---|---|---|---|
| 2.0 | Façade | 0.0% | 0.0% | 0.0% | -5.3% | -5.3% | -5.3% | -5.3% |
| *2.0* | *Structure* | 0.0% | -9.6% | -9.6% | 6.5% | -8.9% | -3.4% | 17.2% |
| 5.0 | Services (MEP) | 0.0% | 0.0% | -3.3% | -3.3% | -3.3% | -3.3% | -3.3% |
| **Total** | **Change in Cost (%)** | **0.0%** | **-3.5%** | **-4.1%** | **1.0%** | **-4.6%** | **-2.6%** | **4.9%** |

### 4.2.3 MIXED-USE

**Structure**

Due to the near identical structural results between the office & mixed-use archetypes, please refer to the discussion in Section 4.2.2 for a discussion around the implications of the structural results.

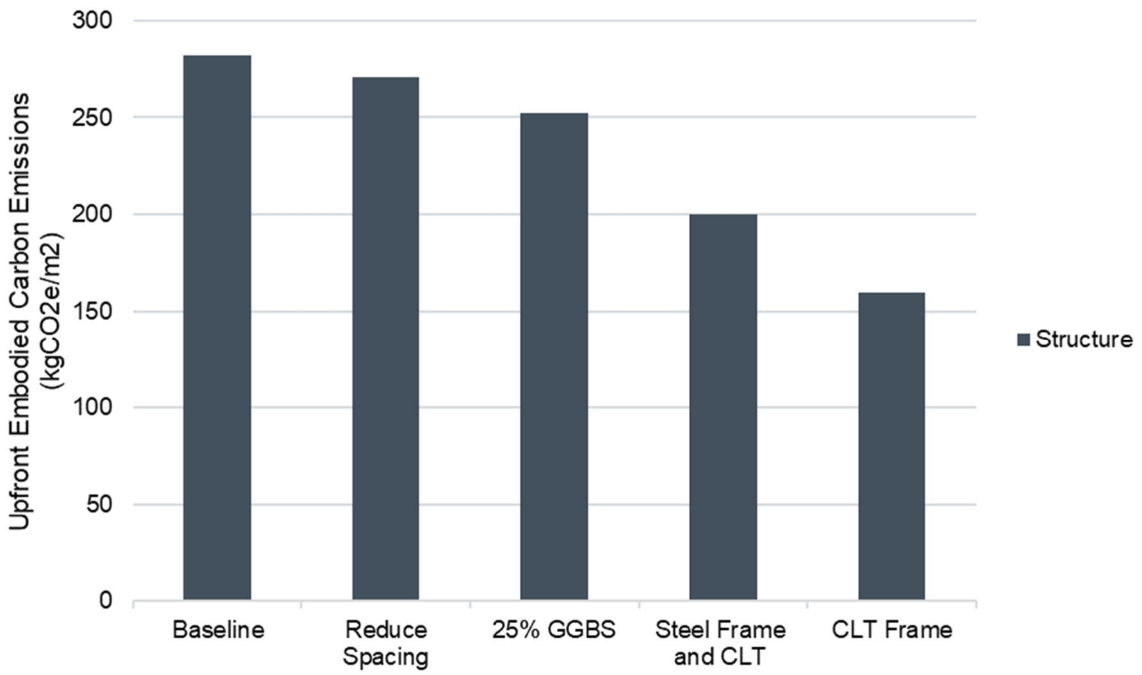



***Figure 4-10 – Impact of structure on carbon emissions for mixed-use archetype.***

### Façade

The baseline total facade cost is around £500 per square metre including different façade systems distributed of the façade surface area of the selected building archetype.

The low carbon façade sees a cost reduction due to change from high-cost high carbon material such as terracotta rainscreen panels to brickworks for the opaque element, with the additional cost associated with recycled aluminium in the curtain walling system off set by this saving as per the office archetype.

- Adopting a greater proportion of recycled aluminium into the framing system and brickwork cladding could lead to a reduction of façade embodied carbon of up to 36% (-44 $kgCO2_e/m^2$).
- Incorporating timber rain screen could lead to a further reduction of 16% (-20$kgCO2_e/m^2$) noting that using timber for residential buildings over 18m in this way is not currently feasible.

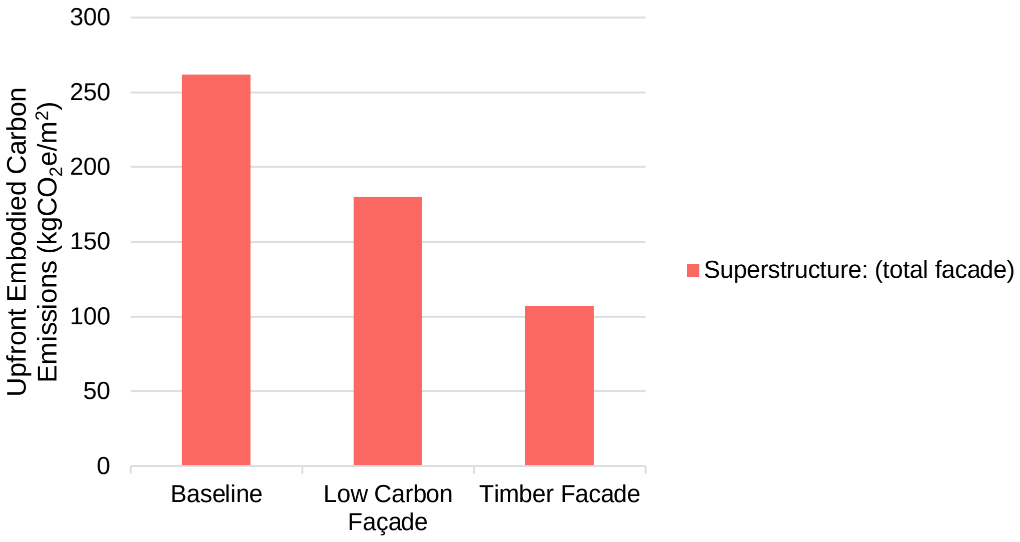



***Figure 4-11 – Impact of facade on carbon emissions for mixed-use archetype.***

### Services

The low carbon scenario for building services was a centralised heating system with underfloor heating and heat interface units in each apartment. *Figure 4-12* Shows that optimising the heating, ventilation, and air conditioning (HVAC) system by moving away from an ambient loop system to a more traditional central hot water and heating system can save 5% of the embodied carbon emissions of the system. This is a direct result of removing secondary heat pumps and fan-coil units in the apartments. The savings are less pronounced here than in the office as the commercial HVAC system remains consistent with the baseline.

- optimising the heating, ventilation, and air conditioning (HVAC) system, and shifting towards an underfloor air distribution system can save up to 5% (-13 $kgCO2_e/m^2$) of the embodied carbon emissions of the system.

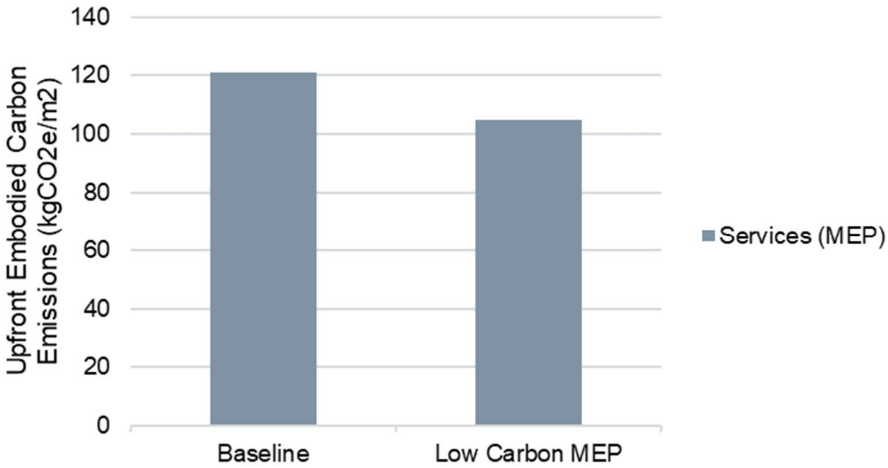



*Figure 4-12 – Impact of services carbon emissions for mixed-use archetype.*

**Carbon Reduction When Combined**

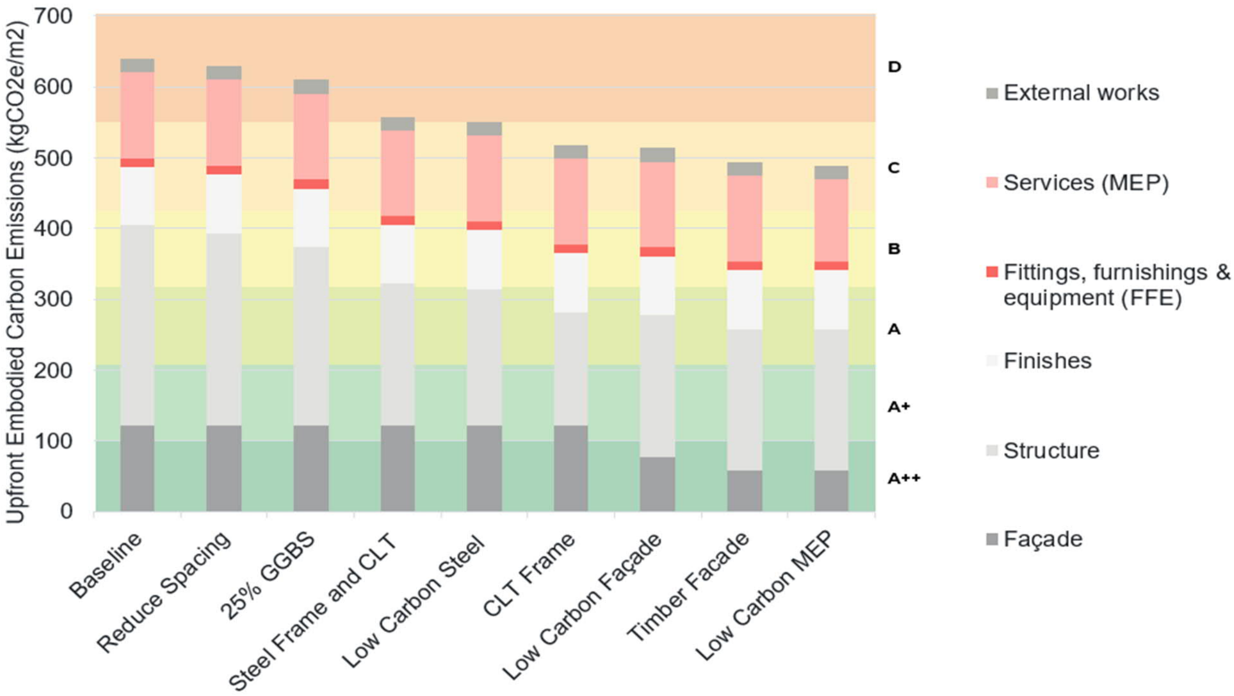



*Figure 4-13 – Carbon and cost impact of intervention when considered in combination for mixed-use archetype.*

### Cost Impact

***Table 4-3 – Cost Impact of each intervention for office.***

| RICS(2017) Category | | Baseline | Reduce Spacing | Low Carbon MEP | Low Carbon Façade | 25% GGBS | Steel Frame and CLT | CLT Frame | Timber Facade |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | Façade | 0.0% | 0.0% | 0.0% | -5.3% | -5.3% | -5.3% | -5.3% | 3.0% |
| *2.0* | *Structure* | 0.0% | -9.6% | 6.5% | 6.5% | -8.9% | -3.4% | 17.2% | 17.2% |
| 5.0 | Services (MEP) | 0.0% | 0.0% | -3.3% | -3.3% | -3.3% | -3.3% | -3.3% | -3.3% |
| **Total** | **Change in Cost (%)** | 0.0% | -3.5% | 1.7% | 1.0% | -4.6% | -2.6% | 4.9% | 6.0% |

## 4.2.4 RESIDENTIAL

### Structure

The impact of applying each of the structural scenarios in sequence from the baseline are shown in Figure 4-14 below. The embodied carbon values shown are for structure only.

The impact of each scenario can be described as follows:

- Starting from the baseline, reducing the grid spacing from 8m to 6m results in a decrease in embodied carbon of 6% (-19kg$CO2_e$/$m^2$). This is an important step as it is independent of material specifications and can greatly reduce the embodied carbon given its impact on floor plate efficiency. When looking at overall structural contributors to embodied carbon, the floor plates are usually the most carbon intensive, and so targeting the spans can have a great impact on overall embodied carbon.
- An increase in cement replacement from 0% (baseline) to 25% has a significant reduction of 13% (-38kg$CO2_e$/$m^2$).
- A similar reduction of 14% (-36kg$CO2_e$/$m^2$) is seen when increasing the cement replacement by a further 25%.

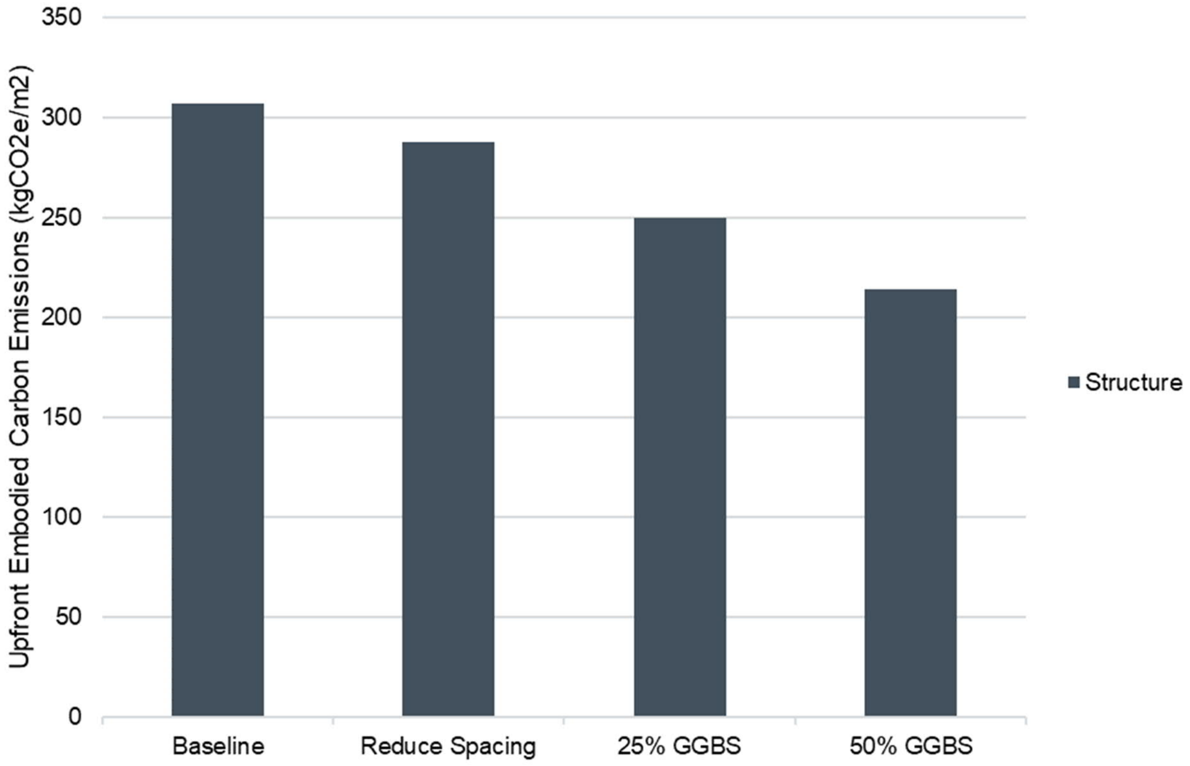



***Figure 4-14 – Impact of structure on carbon emissions for residential archetype.***

**Façade**

The baseline total façade cost is around £1100 per square metre. As for the mixed-use archetype, the terracotta rainscreen included in the baseline are substituted with brickworks to optimise the embodied carbon of the overall build-up. The windows, composed of an aluminium framing, have been substituted by a composite framing, less impactful in terms of embodied carbon content but more expensive.

The low carbon façade sees a cost reduction due to change from high-cost high carbon material such as terracotta panels to brickworks for the opaque element (constituting more than 60% of the façade surface are of the building archetype analysed).

An additional option is reported if a further optimisation is possible and timber components are accepted by Building Control and are aligned with safety requirements. If limited combustibility components made of timber are accepted, the façade sees a slight increase in price justified by a decrease in embodied carbon.

- Adopting a greater proportion of recycled aluminium into the framing system and brickwork cladding could lead to a reduction of façade embodied carbon of up to 31% (-51 $kgCO2_e/m^2$).
- Incorporating timber rain screen could lead to a further reduction of 28% (-73$kgCO2_e/m^2$) noting that using timber for residential buildings over 18m in this way is not currently feasible.

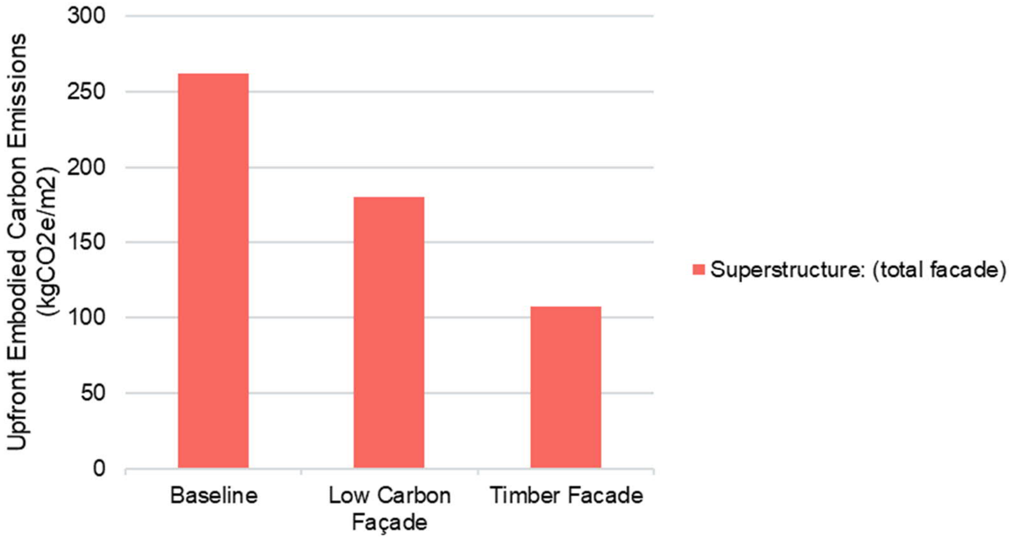



***Figure 4-15 – Impact of facade on carbon emissions for residential archetype.***

**Services**

The low carbon scenario for building services was a centralised heating system with underfloor heating and heat interface units in each apartment. *Figure 4-16* Shows that optimising the heating, ventilation, and air conditioning (HVAC) system by moving away from an ambient loop system to a more traditional central hot water and heating system can save 5% of the embodied carbon emissions of the system. This is a direct result of removing secondary heat pumps and fan-coil units in the apartments. The savings are less pronounced here than in the office as the commercial HVAC system remains consistent with the baseline.

- optimising the heating, ventilation, and air conditioning (HVAC) system, and shifting towards an underfloor air distribution system can save up to 5% (-13 $kgCO2_e/m^2$) of the embodied carbon emissions of the system.

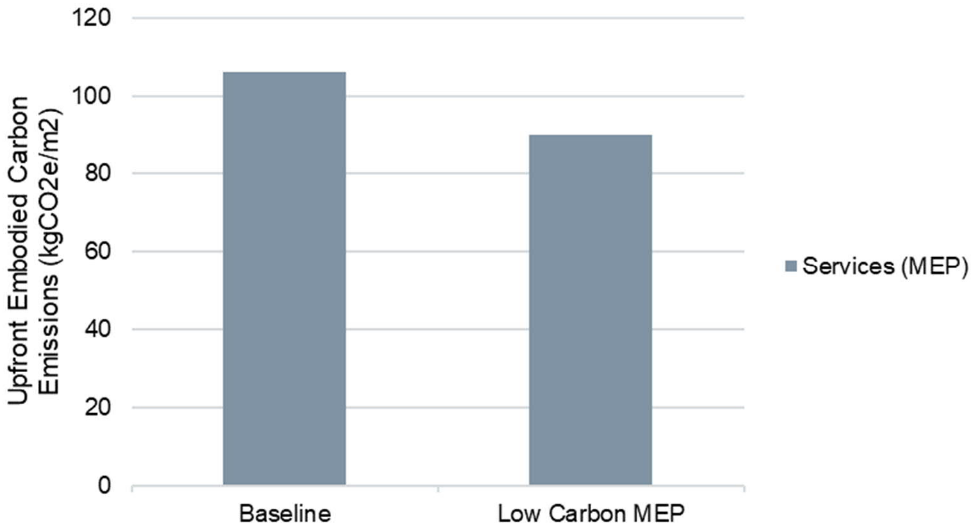



***Figure 4-16 – Impact of services carbon emissions for residential archetype.***

## Carbon Reduction When Combined

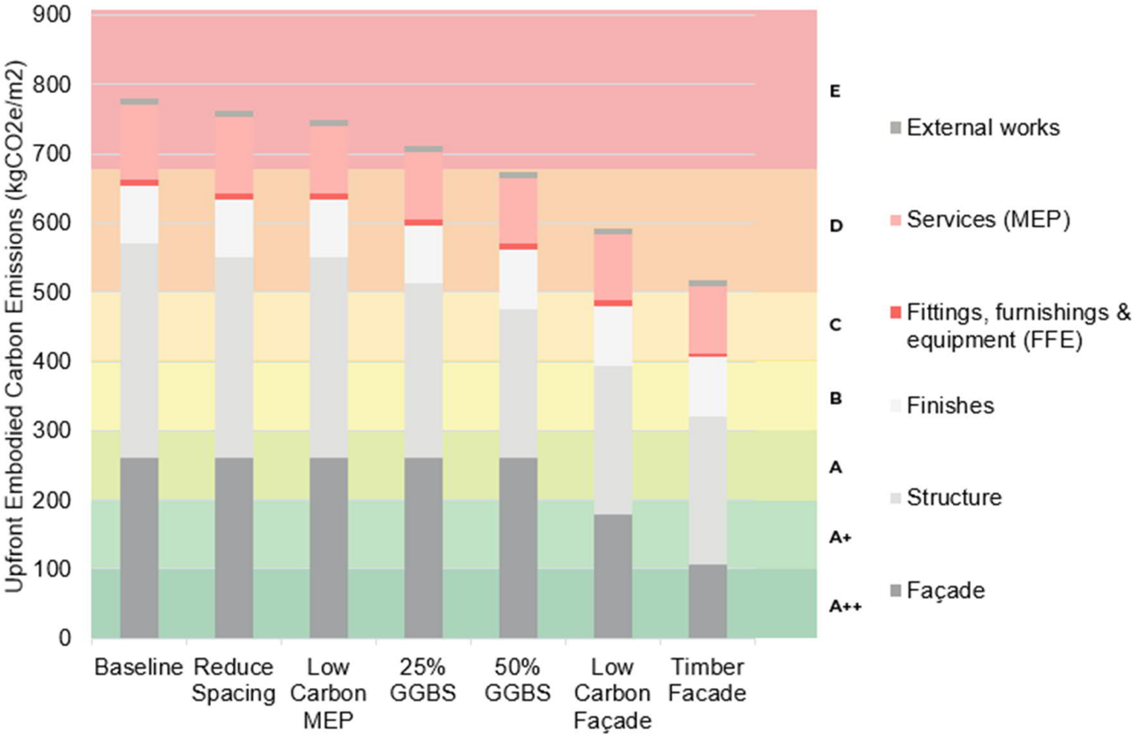



***Figure 4-17 – Carbon and cost impact of intervention when considered in combination for residential archetype.***

### Cost Impact

***Table 4-4 – Cost Impact of each intervention for the residential archetype.***

| RICS(2017) Category | | Baseline | Reduce Spacing | Low Carbon MEP | Low Carbon Façade | 25% GGBS | 50% GGBS | Timber Facade |
|---|---|---|---|---|---|---|---|---|
| 2.0 | Façade | 0.0% | 0.0% | 0.0% | -14.8% | -14.8% | -14.8% | -2.5% |
| 2.0 | Structure | 0.0% | -1.8% | -1.8% | -1.8% | 3.5% | 10.6% | 10.6% |
| 5.0 | Services (MEP) | 0.0% | 0.0% | -9.6% | -9.6% | -9.6% | -9.6% | -9.6% |
| **Total** | **Change in Cost (%)** | 0.0% | -0.5% | -2.0% | -6.0% | -4.6% | -2.7% | 0.6% |

The Building Regulations require that any residential building with a height to the last occupied floor from ground level greater than 18m should not have combustible material in the external façade construction.  Therefore, in line with current fire Regulations, load bearing cross laminated timber framed residential buildings above 18m are not feasible at this current time. The implications on this report are that the residential archetype has not included any timber within any scenarios, limiting the possible carbon reductions relative to the office & mixed-use archetypes as a result. When using the results within this report, it should be noted that inclusion of timber would be possible for residential buildings with a height from ground to the last occupied floor of less than 18m, bringing with it additional carbon benefits.

Given the inability to use timber on the residential archetype, there are fewer structural interventions available relative to the mixed-use & office archetypes. The introduction of cement replacement has a significant reduction of 74kg$CO_2$e/$m^2$ for this archetype from the baseline to 50% GGBS, which is exactly why it is such a popular cement substitute; this is nearly half a LETI banding in itself. A key issue with GGBS is it is a finite resource which is nearly fully utilised across the globe. Specifying high quantities on one project is therefore likely to result in a reduction of use in another location thus balancing each other out and being unlikely to reduce global emissions.[7] If such residential schemes are serious about carbon targets then it is even more important to consider measures which encourage an efficient structural design first and foremost (e.g. sensible spans, restricting or limiting basement space, reducing quantity of transfer structures required). In future however, it is possible that alternative low-carbon cement replacements may become both more available and viable and so their inclusion within this report is relevant.

[7] The efficient use of GGBS in reducing global emissions (IStructE, 2023) https://www.istructe.org/resources/guidance/efficient-use-of-ggbs-in-reducing-global-emissions/

### 4.2.5 SCENARIO INCLUDING BASEMENT

As well as the structural options shown in Table 3-1, a further scenario was explored whereby a single-storey basement was added to each of the baseline options. The carbon results for this are shown in the two tables below. The reason the basement results are described separately here rather than being included alongside the other results as the change in GIA skewed the resulting cost data, making the results non-comparable.

Please note that the values in the table below are for the **structure only**.

***Table 4-5 – Total carbon (kgCO₂e, A1-A5)***

| | Baseline | Baseline with Basement | Uplift (Absolute) | Uplift (%) |
|---|---|---|---|---|
| Mixed-Use / Office | 2,558,304 | 3,182,976 | 624,672 | 24% |
| Residential | 2,121,984 | 2,488,320 | 366,336 | 17% |

***Table 4-6 – Embodied carbon (kgCO₂e/m², A1-A5)***

| | Baseline | Baseline with Basement | Uplift (Absolute) | Uplift (%) |
|---|---|---|---|---|
| Mixed-Use / Office | 282 | 307 | 25 | 9% |
| Residential | 307 | 320 | 13 | 4% |

In absolute terms (kg$CO_2$e), including a single storey of basement has a marked increase in carbon for all options, with a 24% increase for the mixed-use & office and a 17% increase for the residential. This is disproportionate compared to including an additional super-storey level due to the carbon intense retaining walls that are required, and the deeper foundation slab.

When the carbon values are normalised across the GIA, the % uplift reduces as the benefit of the increased GIA is incorporated, however an increase of 9% for both mixed-use & office and a 4% increase for the residential are still seen. Importantly these increases in embodied carbon are seen even when carbon associated with enabling works or groundworks are included, so in reality the increase in embodied carbon for adding basements is likely to be far higher.

It should be noted that carbon measurement systems (e.g. LETI, SCORS) make no differentiation between structures with and without basements, meaning it is likely a carbon penalty will be incurred for schemes which choose to incorporate basement space. Deep basements in particular may involve significant site activity and have a disproportionate carbon impact as a result.

### 4.2.6 COMBINED RESULTS

This report corroborates with the previous report by WSP for the West of England, finding that all building typologies can achieve LETI band D for upfront emissions using typical design practices and at no additional cost. Moreover, this report has also found that LETI band C can also be achieved at no additional cost uplift across all building typologies, and that a mixture of adopting cost saving carbon reduction measures (such as removing basements, reducing grid spans and optimising the façade and MEP systems) with more expensive carbon measures (such as introducing CLT floors or a higher percentage of recycled materials and cement replacement) can be adopted to deliver carbon reductions near to cost parity with traditional construction.

As shown by Table 4-7, this study found a similar 8% uplift in cost to achieve a LETI band B for commercial office building, also finding a modest 2% uplift for the mixed-use archetype. It is important to note that while carbon savings at cost parity are achieved, the end product is different as the building design will have a less expensive façade, reduced spans and no basement. Where this report differs from the original findings surrounds greater uncertainty of achieving low and very low carbon emissions (LETI band A or lower).

Due to fire safety restrictions in residential this study found that it would be difficult to achieve a LETI band B or higher for residential with current construction practices, for new buildings over 18m. These may be achievable through using specific low-carbon products or systems (cement replacement, recycled metals) however current market volatility and supply chain issues made these difficult to price, and it is unlikely at this current time that these are deliverable solutions at scale.

This analysis shows that even adopting good practice design and high levels of material substitution, each of the buildings still will not achieve carbon reductions in line with UK Net Zero Target, 1.5 degrees and The Paris Agreement (LETI Band A or below). Achieving further reductions is much more likely to be made possible by re-using structure and materials of existing buildings, by promoting retrofit and the circular economy.

**Table 4-7 – Cost uplift per typology to comply with the letter banding targets of Embodied Carbon Target Alignment work.**

| Building Typology | D, E, F, G | C | B | A | A+, A++ |
|---|---|---|---|---|---|
| **Upfront Embodied Carbon (A1-A5)** | | | | | |
| Office | 0% | 0% | 7% | *Further Measures Necessary* | *Non-compliant* |
| Mixed Use | 0 % | 0% | 2% | *Further Measures Necessary* | *Non-compliant* |
| Residential | 0% | 0% | *Further Measures Necessary* | *Non-compliant* | *Non-compliant* |

## 4.3 IMPLEMENTATION

### 4.3.1 SCOPE

This report has focused on upfront (A1-A5) embodied carbon, following the RICS (2017) assessment methodology. This follows the available guidance at the time of writing and was reasonable and appropriate within the scope of this assessment. However, methods for evaluating the embodied carbon of construction projects are continually evolving, as demonstrated by the release of RICS 2.0 assessment methodology during the preparation of this report. It is therefore essential that any new policy takes into consideration other regulatory and industry assessments, and that the results of this work are viewed in the context of this evolving calculation process.

**Greater London Authority Whole Life-Cycle Carbon Assessment Guidance**

The Greater London Authority (GLA) Whole Life-Cycle Carbon Assessment guidance is a key component in London's strategy to mitigate climate change. This methodology is by definition a whole life-cycle carbon assessment, including both up-front and whole life embodied carbon emissions and also operational emissions. A critical aspect of this methodology is the requirement for major developments to calculate and report whole life-cycle carbon emissions in a standardised format, forming a mandatory part of the planning application process. The guidance stipulates calculation standards and reporting protocols, ensuring consistency and accuracy across developments. The GLA also periodically updates this guidance to reflect the latest advancements in sustainable building practices and carbon reduction technologies. These regular revisions ensure that the methodology remains at the forefront of addressing climate change, aligning with evolving environmental goals and technological innovations in the construction industry.

The GLA requirement to undertake WLC assessments for major projects in London has been instrumental in improving industry knowledge and understanding of embodied carbon in construction projects. However, one criticism has been that the embodied carbon target and aspirational targets have not been set low enough to discourage demolition, and developers can proceed with near to business-as-usual practices with limited restrictions. Despite this, the framework and reporting process required to be undertaken by developers is a sound standardised approach that has undertaken rigorous review and has been in action since March 2022, and any new policy should look to align with this existing policy.

**GLA Optioneering Study**

The City of London issued its first Whole Life Carbon Optioneering Planning Advice Note in March 2023 which requires:

WLC Assessment, in line with the GLA's proposed methodology, to be undertaken at pre-application and planning stages, bringing carbon accounting to early stages of design planning.

- Developers to calculate and report the WLC of realistic and feasible options at pre-application where there are existing buildings on site.
- The emissions associated with a minor refurbishment, major refurbishment, significant refurbishment & extension, and new-build options should be compared – compelling clients and design teams to look for opportunities to minimise demolition.
- A WLC reporting dashboard to increase consistency of supporting carbon documents across pre-app and planning application submissions.

- Scope and assumptions across all options to be consistent and presented in a transparent way, without bias.
- An independent third-party verification to be carried out on all optioneering assessments as a quality assurance mechanism.

**RICS 2017 vs RICS 2.0**

In November 2023, during the development of this project, The Royal Institute of Chartered Surveyors (RICS) updated their Whole Life Carbon Assessment for the Built Environment. The second edition of the RICS standard represents a significant expansion from its 2017 predecessor, primarily focusing on enhancing consistency in cost and carbon reporting, as well as benchmarking for both new builds and existing assets. This second edition aligns with the International Cost Management Standards (ICMS) 3rd Edition and the Built Environment Carbon Database (BECD), facilitating a uniform output in these areas. Moreover, it integrates guidance from other professional bodies such as CIBSE, IStructE, and CWCT, particularly concerning embodied carbon measurement. This edition sets a comprehensive standard for assessing whole life carbon throughout the entire asset life cycle. It has broadened its scope to include both buildings and infrastructure, making Whole Life Carbon Assessments (WLCA) applicable across all sectors and asset types. The integration with existing software tools has been improved, making the standard more accessible to SMEs, which form a significant portion of RICS members.

The second edition of the RICS framework brings in updated industry-agreed definitions for carbon terminology to ensure clarity and uniformity in approach. It introduces a standardised method for assessing risk in carbon assessment reporting and addresses uncertainties in WLCA reporting by mandating the calculation and reporting of a contingency allowance. This allowance varies based on the stage of WLCA production and the quality of data used. Technically, the new edition delves deeper into carbon data sources, conversion factors, and distinguishes between manufacturer-specific, sector average, and generic data. It also provides additional guidance on grid and material decarbonisation, carbon sequestration, and biogenic carbon. Furthermore, it includes guidance on retrofit and alignment with the circular economy, enabling professionals to work with the most up-to-date standards.

RICS 2.0 has been published in November 2023, and is expected to come into force in July 2024.

**Industry Best Practice**

RICS Guidance 'Whole Life Carbon Assessment for the Built Environment' acts as a reporting framework, however refers specifically to guidance from other institutions such as IStructE, CWCT and CIBSE for details which is evolving at a separate pace to RICS guidance. As a result, new policy should refer to specific methodologies outlined by Engineering Institutions specifically, IStructE "How to calculate embodied carbon (Second edition)"[8], CWCT "How To Calculate The

[8] How to calculate embodied carbon (Second edition) (IStructE, 2022) https://www.istructe.org/resources/guidance/how-to-calculate-embodied-carbon/

Embodied Carbon Of Facades: A Methodology"[9] and CIBSE "TM65 Embodied Carbon in Building Services"[10].

**UK Net Zero Building Standard**

The Net Zero Carbon Buildings Standard, due to be released in 2024, brings together Net-Zero Carbon requirements for all major building types, based on a 1.5°C trajectory. Leading organisations BBP, BRE, the Carbon Trust, CIBSE, IStructE, LETI, RIBA, RICS, and UKGBC have joined forces to all champion this initiative. This standard aims to provide the industry with a clear and robust framework to demonstrate that their built assets are net zero carbon, aligning with the nation's climate goals. To achieve this, the standard will integrate as much as possible with existing net zero initiatives and standards, creating a cohesive approach.

This forthcoming Standard will detail specific metrics to evaluate net zero carbon performance, including setting performance targets or limits. Key metrics likely to be included are energy usage, upfront embodied carbon, and lifecycle embodied carbon. Additional considerations such as space heating/cooling demand and peak load may also be incorporated. The standard will address carbon accounting methodologies, procurement of renewable energy, and strategies for managing residual emissions, including carbon offsetting. While the scope and output of the standard could evolve during its development, it is expected that claims of net zero carbon performance will need validation through in-use measured data. There is also potential for interim verification at the design stage or post-construction pre-operation phase.

The application of this approach will span across both existing and new buildings, encompassing a range of typologies such as homes, offices, educational facilities, industrial and retail spaces, hotels, and healthcare buildings. Initially, the focus will be on the most common building types, particularly those with robust existing performance data to inform target setting. Notably, the standard is not intended to apply to infrastructure projects.

It is expected that The UK Net Zero Building Standard, when released, will supersede the LETI and RIBA embodied carbon targets referenced by this report. Therefore, it is strongly recommended that any policy looking to set embodied carbon targets should be updated once the standard is released.

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[9] How To Calculate The Embodied Carbon Of Facades: A Methodology (CWCT, 2023) https://www.cwct.co.uk/pages/embodied-carbon-methodology-for-facades

[10] TM65 Embodied carbon in building services: a calculation methodology (CIBSE, 2021) https://www.cibse.org/knowledge-research/knowledge-portal/embodied-carbon-in-building-services-a-calculation-methodology-tm65

### 4.3.2 PLANNING CONSIDERATIONS

**Impact on Energy Consumption**

Although it is possible to achieve both low embodied carbon and low operational emissions, one undesirable side-effect of a policy looking to regulate and reduce embodied carbon emissions is the adverse effect of increasing operational emissions by reducing the thermal performance of the building envelope. This reduction in performance may restrict a buildings ability to achieve, for example a high NABERS score for commercial buildings or Passivhaus Certification for residential developments. This is particularly the case for residential buildings where the Passivhaus standard requires extremely high performing façade systems, requiring a higher embodied carbon. This is the case, unless extremely low-carbon materials are used which are currently unavailable on the mass market.

This may represent a false trade-off as the UK grid is set to decarbonise, and new developments are required to use all-electric heating systems. As a result, the operational carbon emissions from new developments are expected to be far lower than the embodied carbon emissions of a construction project. Furthermore, these emissions are emitted over the predicted lifespan of the project 30-60 years and subsequently spend less time in the atmosphere contributing towards global climate breakdown. Adopting a whole life carbon approach, such as following the GLA whole life-cycle carbon methodology, will address this issue and ensure that upfront embodied carbon is balanced against, operational carbon emissions.

**Basements**

As discussed in Section 4.2.5 basements are a key source of embodied carbon emissions for new developments. They are also typically the most expensive floor of a building to construct, particularly if there are atypical groundworks required. Therefore, by restricting the construction of new basements in London, it is likely that both a large cost and carbon saving can be achieved. However, basements also provide useful area for parking, bike storage and building services which if removed will need to be relocated to the above ground building.

The subsequent reduction in total lettable floor area as a result of removing the basement is significant (12.5% in the case of this study), and this reduction in overall floor area has a negative financial implication on overall scheme profitability. Therefore, policy looking to discourage the use of basements on the basis of both cost and carbon, could look to provide other financial incentives to developers, by reducing height restrictions on the project to enable an additional floor to create space for amenity and building services plant above ground.

**Façade Planning Constraints**

Recently published amendments to Approved Document B of the Building Regulations confirm that in buildings with a residential purpose and a storey of 18m or more in height, elements such as cladding, balconies, and other external surfaces must achieve class A1 or A2-s1, d0.

However, there is a growing emphasis on sustainability in construction, and there has been an increased interest in exploring alternative, more sustainable materials, including engineered timber products that may have improved fire resistance. Changes in Building Regulations and standards to accommodate sustainable building practices could happen, and some jurisdictions have been revisiting and updating their codes to reflect advancements in materials and construction methods.

For this reason, the further optimisation has been included in this document as a possible scenario that could incur in the foreseeable future.

**Higher recycled content of glass and aluminium**

The demand for sustainable and recycled façade materials has been growing due to increased awareness of environmental issues and a desire to reduce the carbon footprint of façade systems. Limited supply occurs when there aren't enough sources or manufacturers providing these sustainable materials, which can result in a constrained market. Many construction projects are now aiming to achieve specific environmental certifications and adhere to circular economy principles. This involves using recycled or recyclable materials to minimise waste and environmental impact. The emphasis on meeting these goals contributes to a surge in demand for materials that fulfil these criteria, specifically glass and aluminium as main components from window and curtain walling in facades.

The combination of high demand and limited supply creates a scenario where prices can become volatile. As demand outpaces supply, prices may increase, and the market can experience fluctuations. The price volatility of recycled aluminium and glass presents a risk in project budgeting and cost management: it becomes challenging to estimate and control costs effectively when the prices of these materials are unpredictable and dependence on a single source of supply exacerbates this risk. To mitigate risks associated with a single source of supply, cladding contractors may explore diversifying their supply chain, when manufacturers and suppliers will align their market offer.

**Demolition and Enabling Works**

In line with the IStructE guidance document, an allowance has been made in this study for construction and installation under module A5. This includes an allowance for both material wastage and site activities generally.

It should be noted that a limitation of this study is the non-inclusion of an allowance for significant enabling works, which may be likely in a highly constrained area of London such as Westminster and would therefore increase the embodied carbon. Some projects simply not be feasible without extensive and carbon intensive enabling works or supporting structures. Therefore, the potential impact of the RICS categories outside the scope of this assessment, should be assessed on a project-by-project basis.

It should also be noted that the embodied carbon of existing structures has not been considered as part of this study and that some amount of carbon could be saved by reusing these materials on site. Therefore, improving working practices around disassembly in the demolition phase, and embedding these into construction projects should help to increase the supply of secondary raw material, such as aluminium. This is a key part of circular economy principles, and will help to ensure that the supply chain is more robust. Moreover, projects should demonstrate that they have been designed for disassembly, throughout the project lifecycle to ensure that these materials can be recovered at the demolition phase.

### 4.3.3 OFFSETTING

To achieve net zero all remaining carbon emissions from a construction project are required to be offset, including both the construction and operational phase. Overall, the embodied carbon emissions of a new developments today are expected to be higher than its operational carbon emissions. This is particularly in the case of new all-electric developments which can achieve even lower operational carbon emissions as the electricity grid is decarbonising, the relative significance of embodied carbon emissions is expected to be even higher.

Currently, there is no tax or carbon offset required for embodied carbon emissions. Operational emissions are taxed through the Greater London Authority (GLA) at 95 £/t$CO_2$ with the aim of encouraging the use of on-site renewables to reduce the operational carbon emissions of a new development[11]. It is not known if this would be an appropriate price for offsetting the embodied carbon emissions of new developments. Careful investigation of an appropriate carbon offsetting price specific for providing advantage to low carbon alternatives is recommended, as part of a separate piece of work. Careful consideration must be given to avoid creating loopholes or disincentives for comprehensive carbon reduction. For example, if projects such as low-rise timber housing could avoid GLA operational carbon payments as a result of their low embodied carbon, this could diminish the reduction efforts on operational carbon leading to higher overall emissions. A whole life-cycle approach to carbon pricing could offer the most balanced solution, ensuring that all aspects of a building's carbon footprint are addressed.

### 4.3.4 BREEAM CONSIDERATIONS

A recommendation would be for the policy to instruct a Whole Life Carbon (WLC) assessment (i.e. as per Embodied Carbon Target Alignment), to promote carbon literacy and wholistic thinking on reducing emissions. Then this WLC assessment could feed into any BREEAM credits targeted by each design team (i.e. Mat 01, Mat 02, Mat 03, Mat 05 etc.). BREEAM could therefore be considered as a complementary assessment to the requirements for the net zero carbon policy, which aims to ensure that developments consider sustainability in a holistic way.

[11] Carbon offset fund guidance (WCC, 2023) https://www.westminster.gov.uk/planning-building-control-and-environmental-regulations/planning-policy/other-planning-guidance-support-policies/carbon-offset-fund-guidance

# 5 CONCLUSIONS

Some key conclusions to be considered on how the embodied carbon of new developments could be reduced are:

**Structure:**

- The inclusion of and/or size of a basement could have significant impact on the ability of a project to meet its carbon targets; a 9% uplift in $kgCO2_e/m^2$ was seen for the office & mixed-use archetypes, with a 4% uplift for the residential. This is therefore a critical discussion to be had at the start of any project between the client and design team, as not incorporating one can be an easy win with regards to meeting targets. Therefore, policy looking to discourage the use of basements on the basis of both cost and carbon, could look to provide other financial incentives to developers, by reducing height restrictions on the project to enable an additional floor to create space for amenity and building services plant above ground.
- Design decisions which are independent of material type & procurement routes should be explored as a first means when looking for opportunities to reduce carbon emissions. A 4% reduction in $kgCO2_e/m^2$ was seen in the office & mixed-use schemes when reducing the grid spacings, with an equivalent 6% reduction for the residential. When looking at overall structural contributors to embodied carbon the floor plates are usually the most carbon intensive, and so targeting the spans can have a great impact on overall embodied carbon. An efficient and sensible design reduces the risk that the design team would need to commit to ambitious (and potentially expensive) material specifications early on. A significant cost saving of 10% for the office & mixed-use was also seen when reducing the grids, although the saving was less pronounced (2%) for the residential as the grid spacings were already efficient at 8m.
- Given the restrictions around the use of timber within residential schemes above 18m, there are few possible identified interventions available for this archetype apart from increasing cement replacements. The most common cement replacement, GGBS (ground granulated blast furnace slag), is a limited and constrained resource that is nearly fully utilised across the globe. Specifying high quantities on one project is therefore likely to result in a reduction of use in another location thus balancing each other out and being unlikely to reduce global emissions.[12] For such schemes it is therefore important to consider measures which encourage an efficient structural design first and foremost (e.g. sensible spans, restricting or limiting basement space, reducing quantity of transfer structures required). In future however, it is possible that alternative low-carbon cement replacements may become both more available and viable and so their inclusion within this report is deemed relevant.
- For the office & mixed-use archetypes, the largest reduction in embodied carbon was seen with the introduction of CLT flooring (-21%). As previously stated, the floor plates are typically the largest structural contributor to embodied carbon and this is exemplified by the significant

[12] The efficient use of GGBS in reducing global emissions (IStructE, 2023) https://www.istructe.org/resources/guidance/efficient-use-of-ggbs-in-reducing-global-emissions/

change here. Replacing the steel beams with glulam reduces this by a further 10%. Should certain timber procurement routes be met (as described in Section 3.4.2) then further benefit to the whole life carbon could be obtained through sequestration. As stated above, these procurement routes are not available to residential schemes above 18m, however below this height these benefits could be obtained. To benefit from the introduction of timber, a high cost penalty is incurred; an uplift of around 6% is seen when introducing CLT flooring, with a further 20% to adopt a glulam frame instead of steel.

**Façade:**

- Predicting the embodied carbon contribution of a facade system is challenging due to the multitude of variables involved in the design and construction process. The specific combination of materials, components, and finishes selected for a particular project greatly influences its overall carbon footprint. Assumptions made in different design stages, such as transportation distances and wastage rates, can significantly impact the accuracy of embodied carbon predictions. Transportation emissions depend on the distance materials travel from manufacturing sites to the construction site, and wastage rates affect how efficiently materials are utilised.
- Designing for disassembly and adaptability aligns with circular economy principles, emphasising the ability to reuse and recycle façade components. While these considerations may not be easily quantifiable, they contribute to the overall sustainability of a project. The potential for reuse and recycling at the end of a building's life can influence the embodied carbon over the entire life cycle of the project. The embodied carbon of a facade systems extends beyond just the construction phase. Considering end-of-life scenarios and the potential for material reuse or recycling is crucial for a comprehensive assessment of the project's environmental impact.
- When incorporating low-carbon components into the transparent build-ups of the evaluated building archetypes' facade systems, the reduction in embodied carbon ranges from -28% of Façade Surface Area (for residential archetypes) to -38% of FSA (for office archetypes). The reduction is even more substantial when considering opaque build-ups, with embodied carbon reductions over Façade Surface Area consistently spanning from -34% (residential archetype) to -72% (office archetype). The optimisation of embodied carbon is averaged when assessed over Gross Internal Area, particularly when considering transparent and opaque proportions of the envelope with the specified Window-to-Wall Ratio for different building archetypes.
- When normalising the embodied carbon value over the Gross Internal Area (GIA) and considering both opaque and transparent areas in the specified ratio, the reduction for office archetypes reaches -41%. This reduction is achieved through the substitution of terracotta rainscreen panels and their associated metal substructure with a lighter solution in terms of embodied carbon contribution. This alternative involves a timber rainscreen and the selection of a higher proportion of recycled aluminium in the curtain walling aluminium framing. Further optimisation, such as specifying recycled glass for the curtain walling system, could result in an additional -15% reduction in embodied carbon.
- For the residential archetype, the reduction of embodied carbon over GIA is -31%. This reduction is attributed to the substitution of terracotta rainscreen panels with a brickwork finishing for the external wall and the replacement of aluminium framing with composite framing in the window system. If timber is accepted in compliance with potential updates in building regulations in the

foreseeable future, the incorporation of timber assembly for residential buildings could lead to an additional -28% reduction in embodied carbon emissions.

**Services**

- This study found that making a reduction in MEP embodied carbon was also likely to lead to a reduction in cost as less HVAC plant and distribution systems would be needed to serve the building. Reducing the embodied carbon of the MEP system by swapping out the HVAC system lead to between 1-6% saving on the embodied carbon of the building, while saving between 0.4-4% of the total build cost.

This report aligns with previous findings by WSP, confirming that achieving LETI band D for upfront emissions across all building typologies is feasible using standard design practices without incurring extra uplift. It further reveals that reaching LETI band C is also possible at no additional financial burden. Our study shows that a blend of cost-effective carbon reduction strategies, such as eliminating basements, optimising grid spans, and enhancing façade and MEP systems, with more expensive measures like incorporating CLT floors or using more recycled materials and cement substitutes, can approach cost parity with traditional construction methods. As shown in Table 4-7, we observed an approximate 8% cost increase to attain LETI band B for commercial offices, and a modest 2% for mixed-use buildings. It's crucial to note, however, that while these carbon savings are achievable at comparable costs, the resultant building designs will differ, featuring less expensive façades, shorter spans, and the absence of basements. This report also identifies a greater uncertainty in reaching very low carbon emissions (LETI band A or lower), as a result of uncertainty surrounding the price and availability of recycled construction materials.

This study has been a desk-based assessment, exploring the impact of common measures of reducing embodied carbon across 3 common building archetypes in The City of Westminster. This analysis found that achieving moderate improvements in embodied carbon (equivalent to LETI band C) can be done on cost parity with current building practices, and that achieving good embodied carbon (equivalent of LETI band B) was achievable with only a moderate 2-7% uplift in cost for office and mixed use buildings, by employing a mix of decarbonisation strategies such as: reduced grid spacing, removal of basements, timber and recycled materials. However, this analysis also found that achieving further reductions (LETI band A or lower) would require higher levels of timber or recycled materials not currently available on the market at scale.

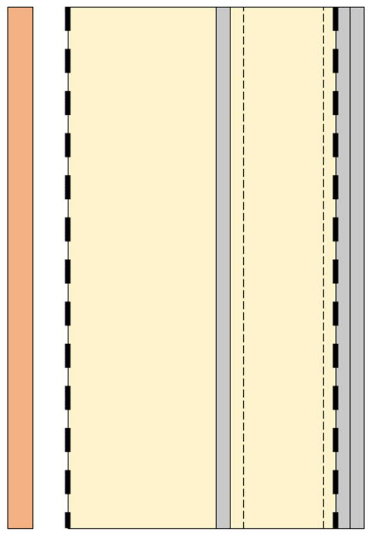
This analysis shows that even adopting good practice design and high levels of material substitution, each of the buildings still will not achieve carbon reductions in line with UK Net Zero Target, 1.5 degrees and The Paris Agreement (LETI Band A or below). Achieving further reductions is much more likely to be made possible by re-using structure and materials from of existing buildings, by promoting retrofit and the circular economy.

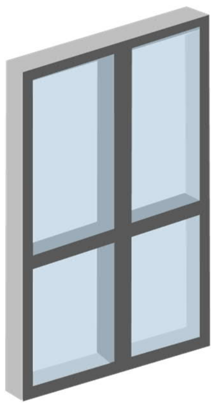
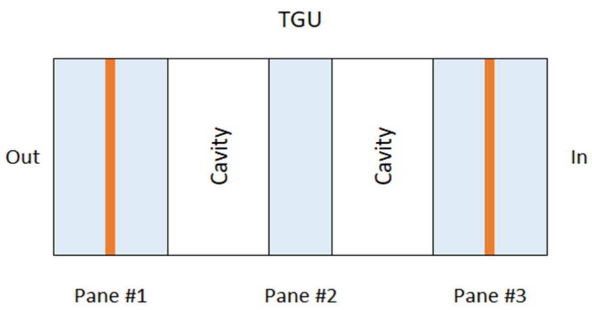
# Appendix A

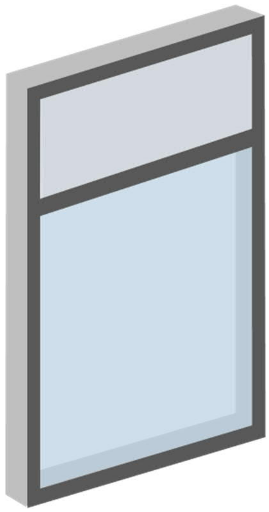
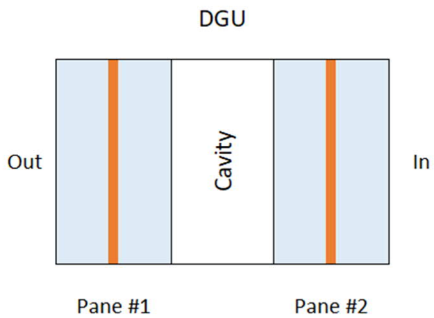
## MODELLING DETAILS

## Appendix A: Modelling details

Tables below list materials included in the opaque and transparent build ups in the façade systems of the baselines.

| **OPAQUE BUILD-UP**<br>(From interior to exterior) |  |
|---|---|
| Plaster Board | |
| Vapour Control Layer | |
| Steel Framing System | |
| Mineral Wool | |
| Cement Particle board | |
| Mineral Wool | |
| Breather Membrane | |
| Aluminium Substructure | |
| Terracotta Cladding | |

| **TRANSPARENT BUILD-UP**<br>WINDOW SYSTEM |  |
|---|---|
| Framing | |
| Triple Glazed Unit (44.2-14-6-14-44.2 laminated heat strengthened low iron glass with selective coatings applied in face 4 and 6)   | |

<table>
<tr><td>TRANSPARENT BUILD-UP<br>CURTAIN WALLING</td><td rowspan="5"></td></tr>
<tr><td>Framing</td></tr>
<tr><td>Double Glazed Unit (66.2-16-66.2 laminated heat strengthened low iron glass with selective coating applied in face 4)<br>
</td></tr>
<tr><td>Bracketry System (Cast-in channel, Bracket, Firestop)</td></tr>
<tr><td>Opaque Spandrel (sandwich panel made of two sheets of 1mm each of aluminium and 200 mm of mineral wool and a terracotta rainscreen with substructure)</td></tr>
</table>

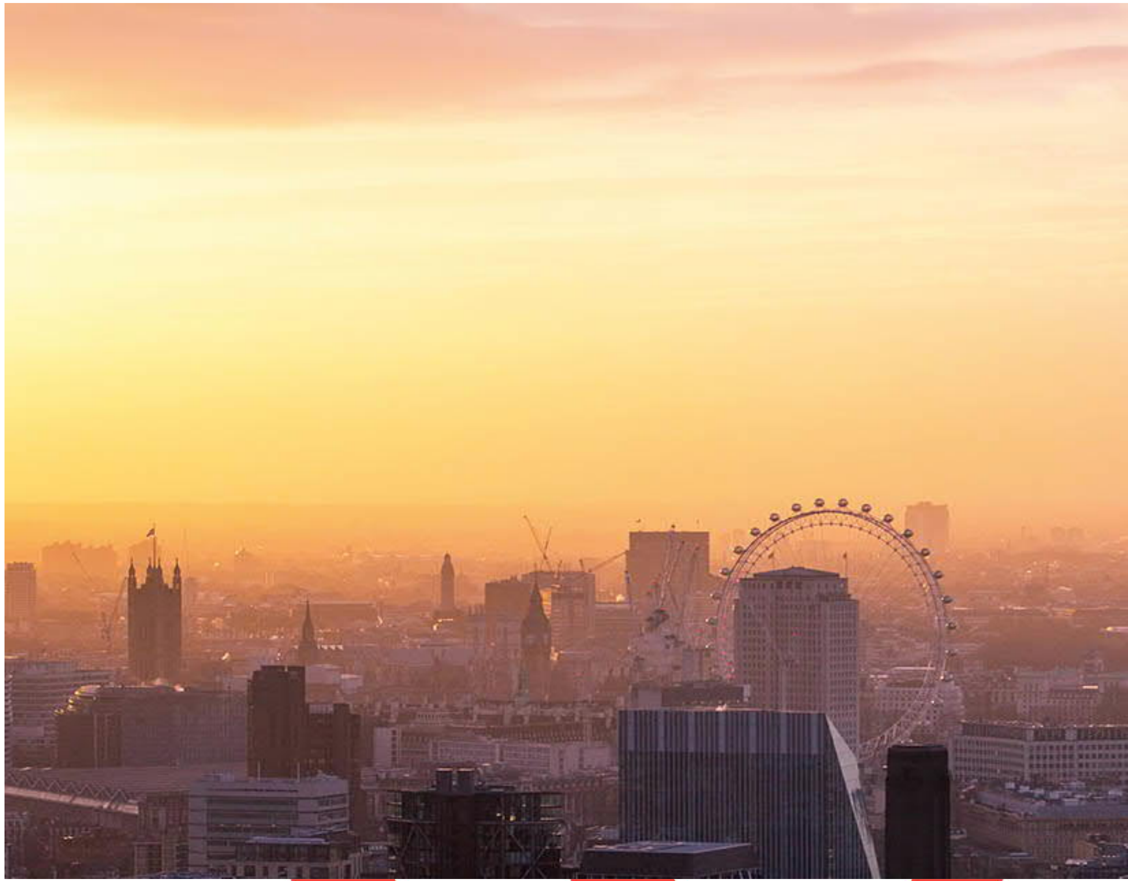
# Appendix B

PRESENTATION SLIDES

# Westminster City Council

## Embodied Carbon Evidence Base

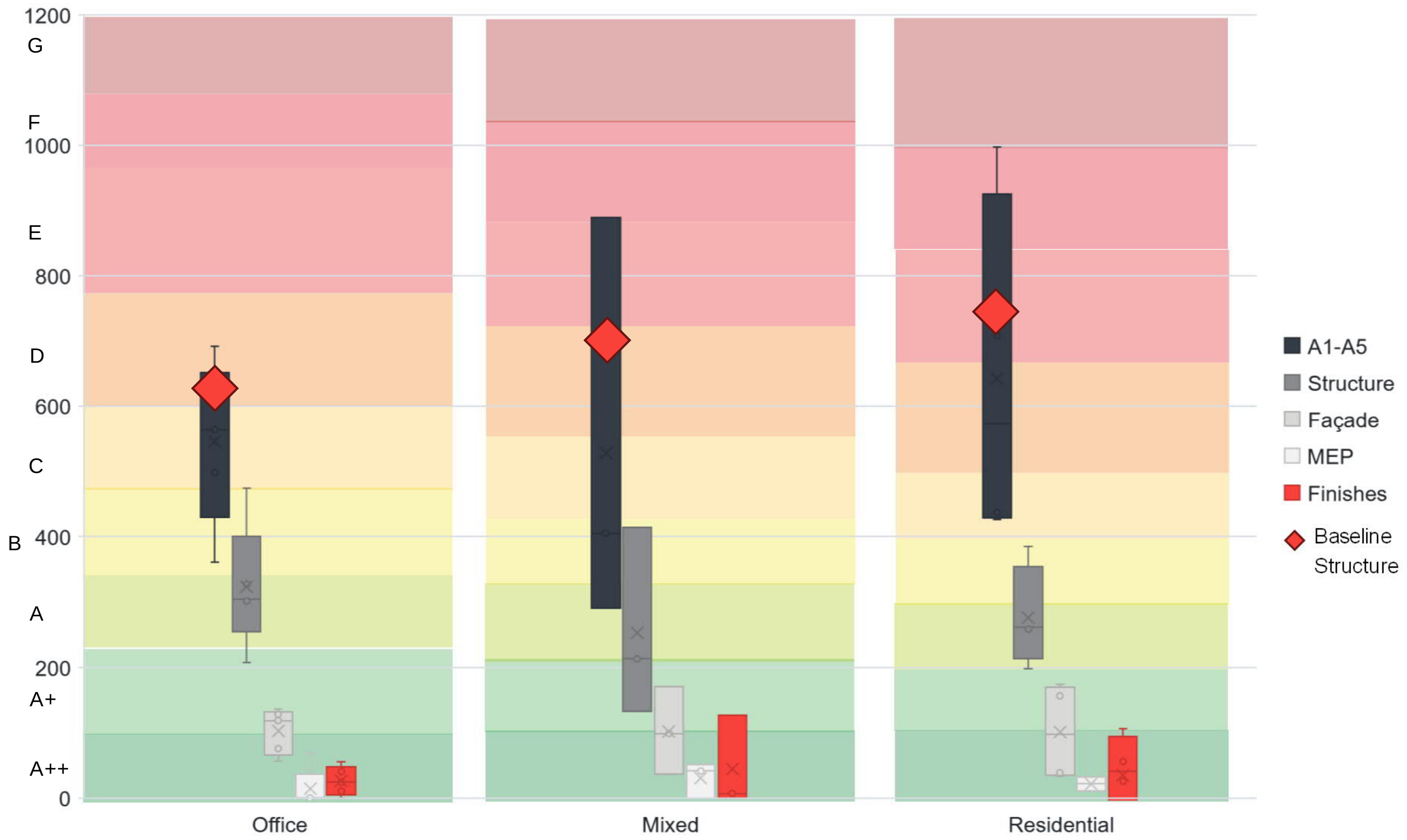
Update #5 | Cost Figures



# Comparing to Benchmarks

| RICS (2017) Framework / GLA WLC Reporting Guide (2020) | | Data Source |
|---|---|---|
| 0.1 | Demolition: Toxic/Hazardous/Contaminated Material Treatment | Excluded |
| 0.2 | Major Demolition Works | Excluded |
| 0.3 | Temporary Support to Adjacent Structures | Excluded |
| 0.4 | Specialist Ground Works | Excluded |
| 1.0 | Substructure | ISTRUCTE Methodology |
| 2.1 | Superstructure: Frame | ISTRUCTE Methodology |
| 2.2 | Superstructure: Upper Floors | ISTRUCTE Methodology |
| 2.3 | Superstructure: Roof | ISTRUCTE Methodology |
| *2.4* | *Superstructure: Stairs and Ramps* | *Based on WSP LCA data* |
| 2.5 | Superstructure: External Walls | CWCT Methodology |
| 2.6 | Superstructure: Windows and External Doors | CWCT Methodology |
| *2.7* | *Superstructure: Internal Walls and Partitions* | *Based on WSP LCA data* |
| *2.8* | *Superstructure: Internal Doors* | *Based on WSP LCA data* |
| 3.0 | Finishes | GLA Benchmark |
| 4.0 | Fittings, furnishings & equipment (FFE) | GLA Benchmark |
| 5.0 | Services (MEP) | CIBSE TM65 Methodology |
| 6.0 | Prefabricated Buildings and Building Units | Excluded |
| 7.0 | Work to Existing Building | Excluded |
| 8.0 | External works | GLA Benchmark |

| | |
|---|---|
| (orange) | Structures ISTRUCTE Calculation |
| (light pink) | In structural scope based of WSP project LCA data |
| (blue) | Façade CWCT Calculation |
| (yellow) | Services CIBSE TM65 Calculation |
| (grey) | Based on GLA Benchmark |
| (white) | Excluded from calculation |



1200
G
F
1000
E
800
D
600
C
B
400
A
200
A+
A++
0
Office
Mixed
Residential
A1-A5
Structure
Façade
MEP
Finishes
Baseline Structure

Cost and Carbon Results

# Office

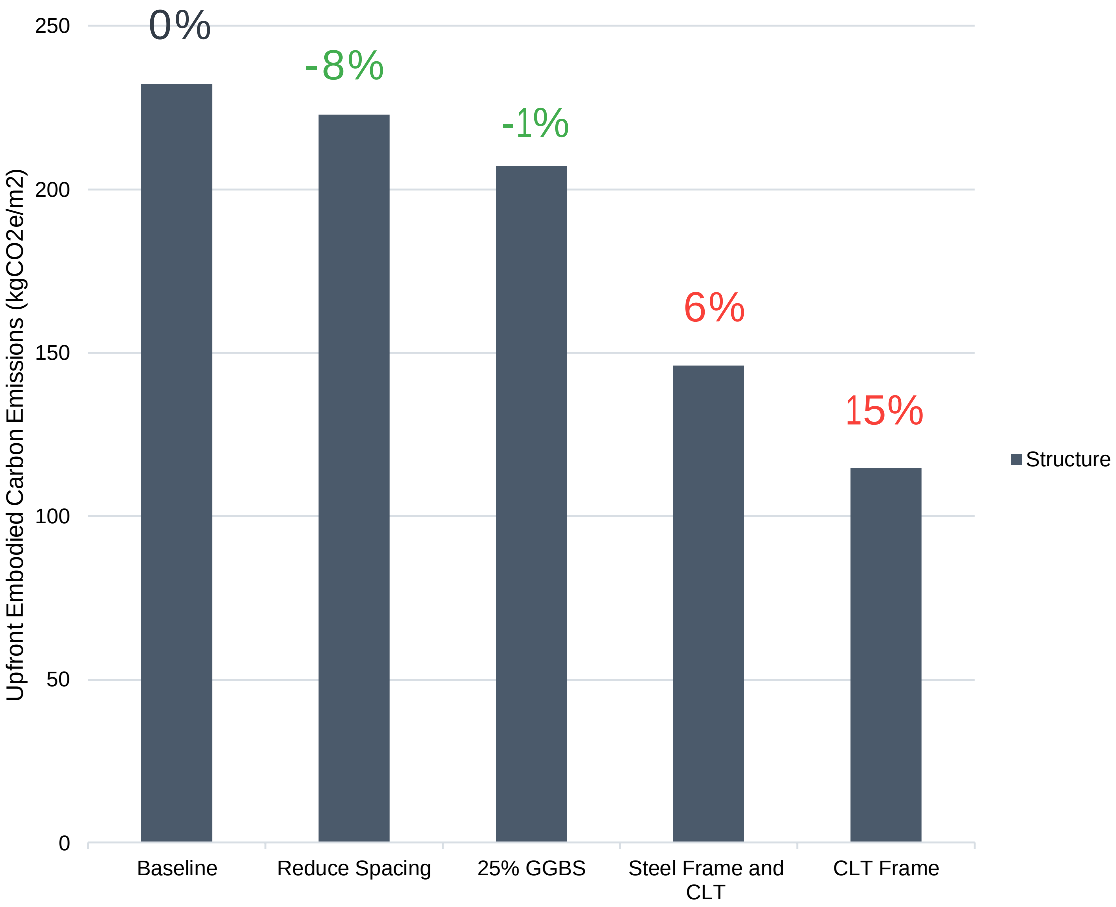
Carbon vs Cost Figures

# Office
# *Structure*

Baseline Total Structural Cost ~£1,700 per square metre, with % savings calculated against this structural cost.

Numbers here represent cost saving against the baseline. Each intervention is combined with the previous set of interventions for both cost and carbon. and presented in sequence.

WSP recommend reducing spans taken as a first step, before adopting other interventions such as CLT.



Carbon vs Cost Figures

# Office

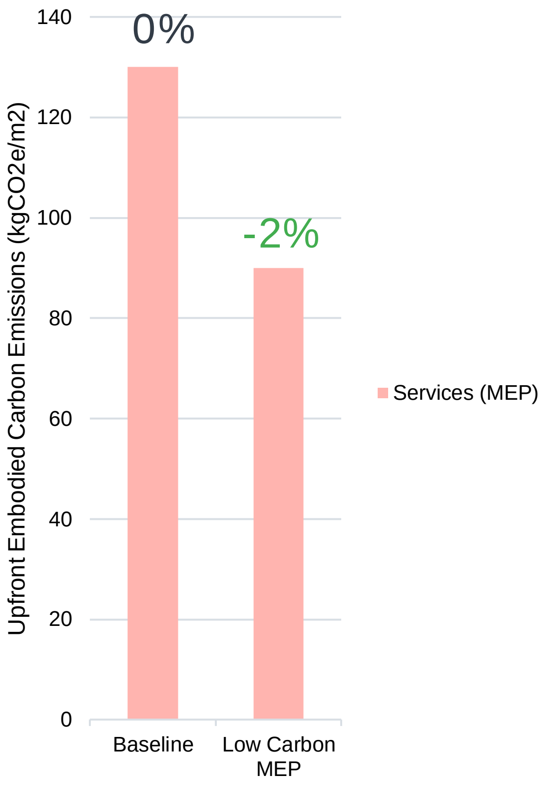
## *Structure*

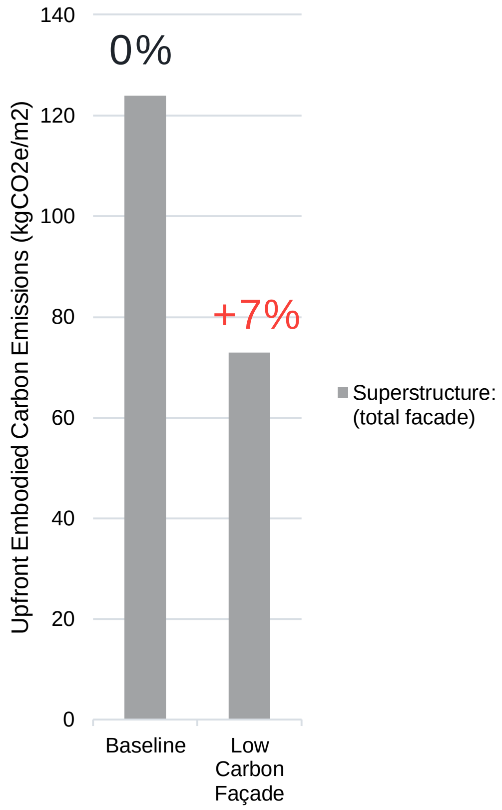
## *MEP*

Baseline total MEP cost ~£900 per square metre, with % savings calculated against this cost. This shows both cost and carbon savings can be made by optimising MEP.

## *Facade*

Baseline total façade cost ~£500 per square metre, with % savings calculated against this cost.



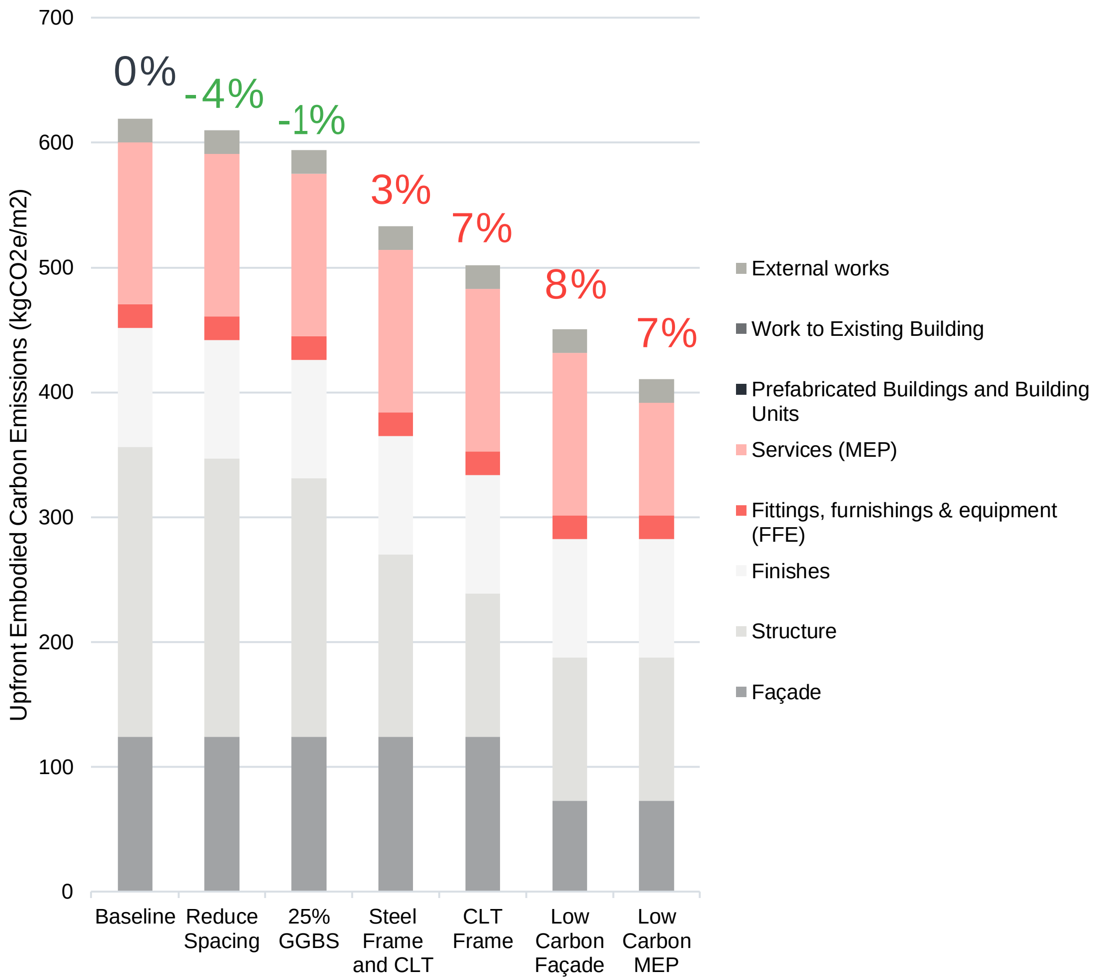



Carbon vs Cost Figures

# Office
## *All Together*

Baseline Total Building Cost ~£3,500 per square metre, with % savings calculated against this notional total.

Numbers here represent cost saving against the baseline. Each intervention is combined with the previous set of interventions for both cost and carbon. and presented in sequence.



Cost and Carbon Results

# Residential

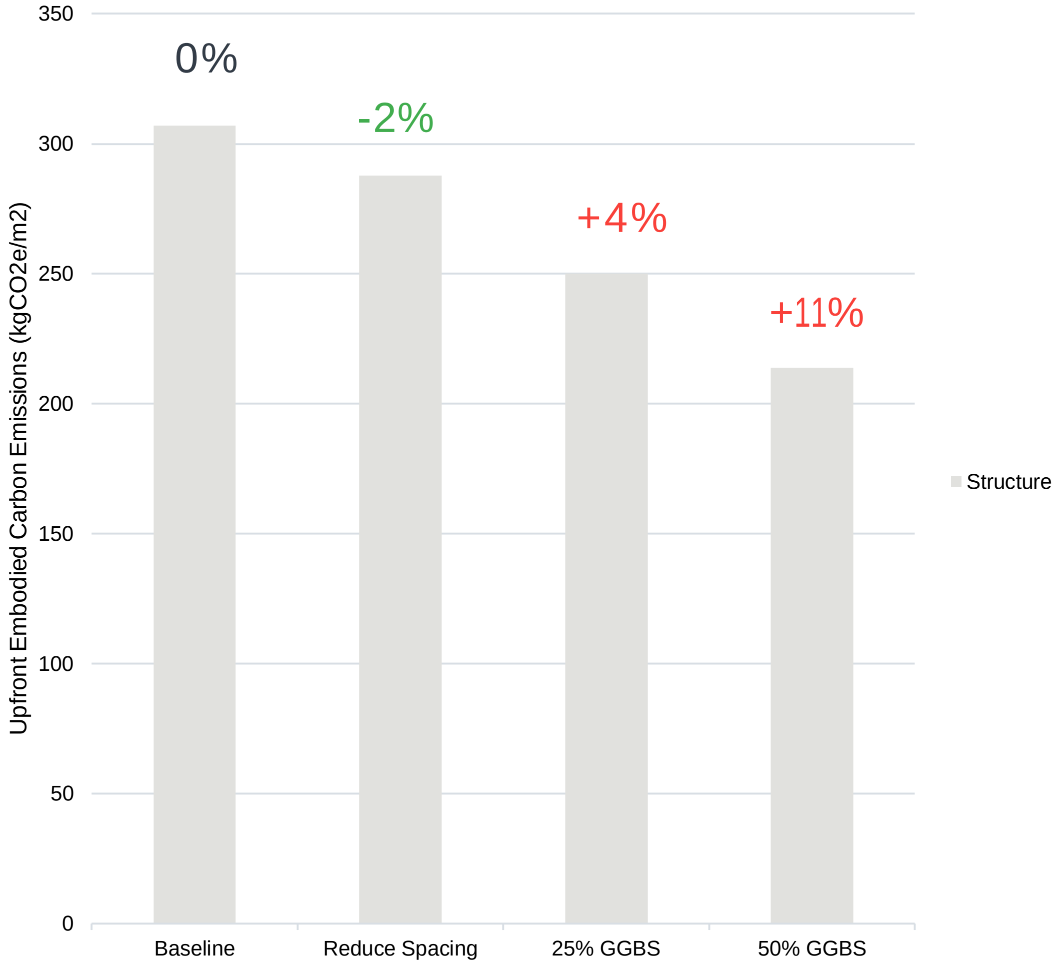
Carbon vs Cost Figures

# Residential *Structure*

Baseline Total Structural Cost ~£1,000 per square metre, with % savings calculated against this structural cost.

Numbers here represent cost saving against the baseline. Each intervention is combined with the previous set of interventions for both cost and carbon. and presented in sequence.

WSP recommend reducing spans taken as a first step, before adopting other interventions such as CLT.



Carbon vs Cost Figures

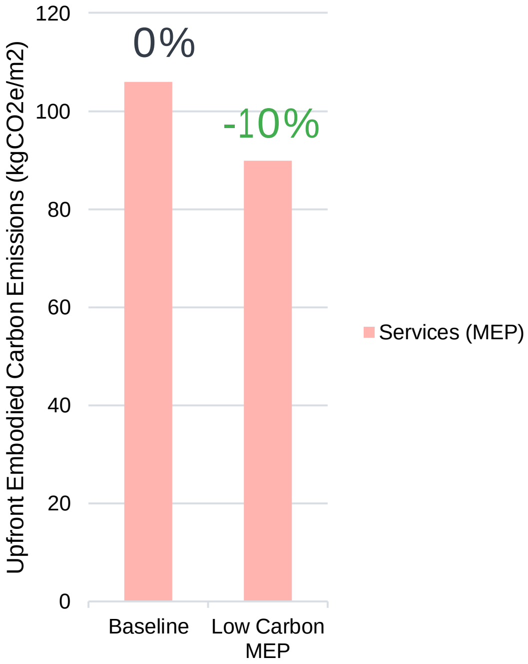
# Residential

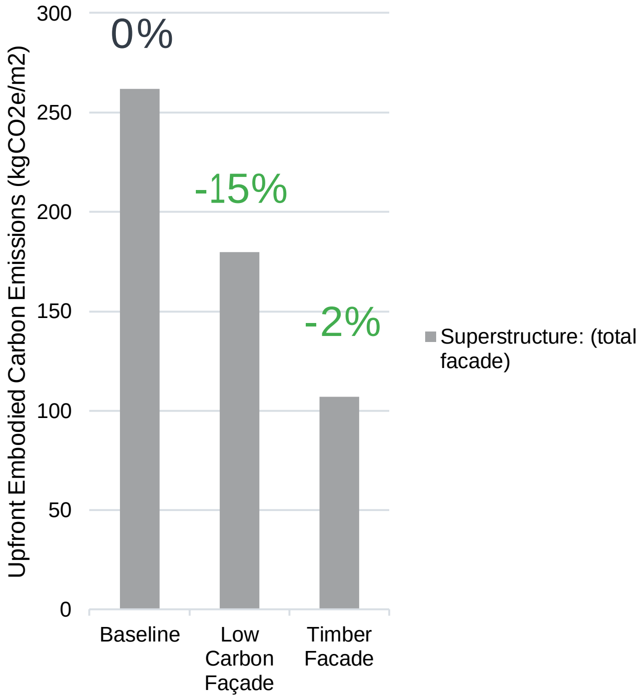
## *MEP*

Baseline total MEP cost ~£600 per square metre, with % savings calculated against this cost. This shows both cost and carbon savings can be made by optimising MEP.

## *Facade*

Baseline total façade cost ~£1100 per square metre, with % savings calculated against this cost.



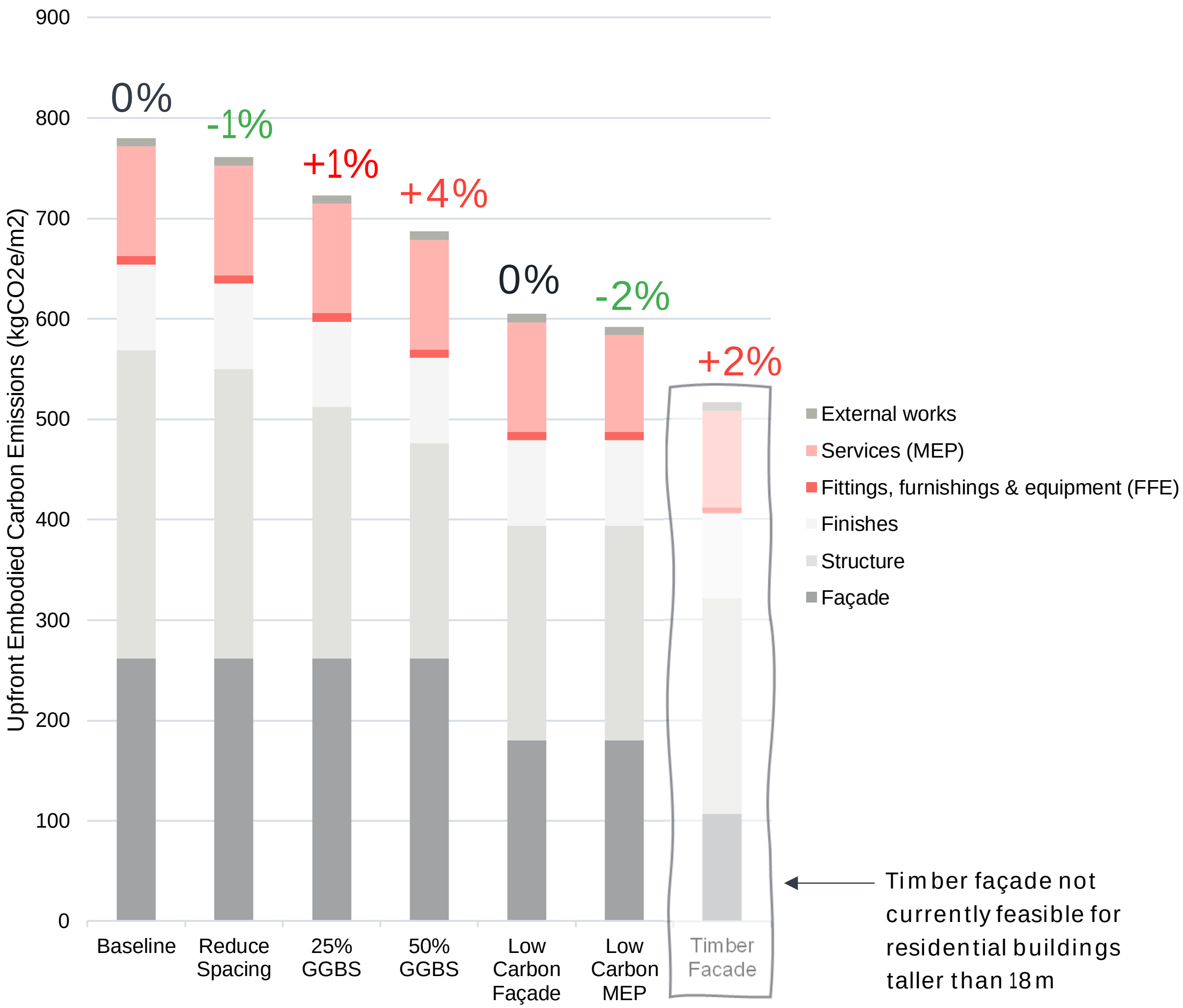



Carbon vs Cost Figures

# Residential
## *All Together*

Baseline Total Building Cost ~£4000 per square metre, with % savings calculated against this notional total.

Numbers here represent cost saving against the baseline. Each intervention is combined with the previous set of interventions for both cost and carbon. and presented as a waterfall chart.



Cost and Carbon Results

# Mixed-Use

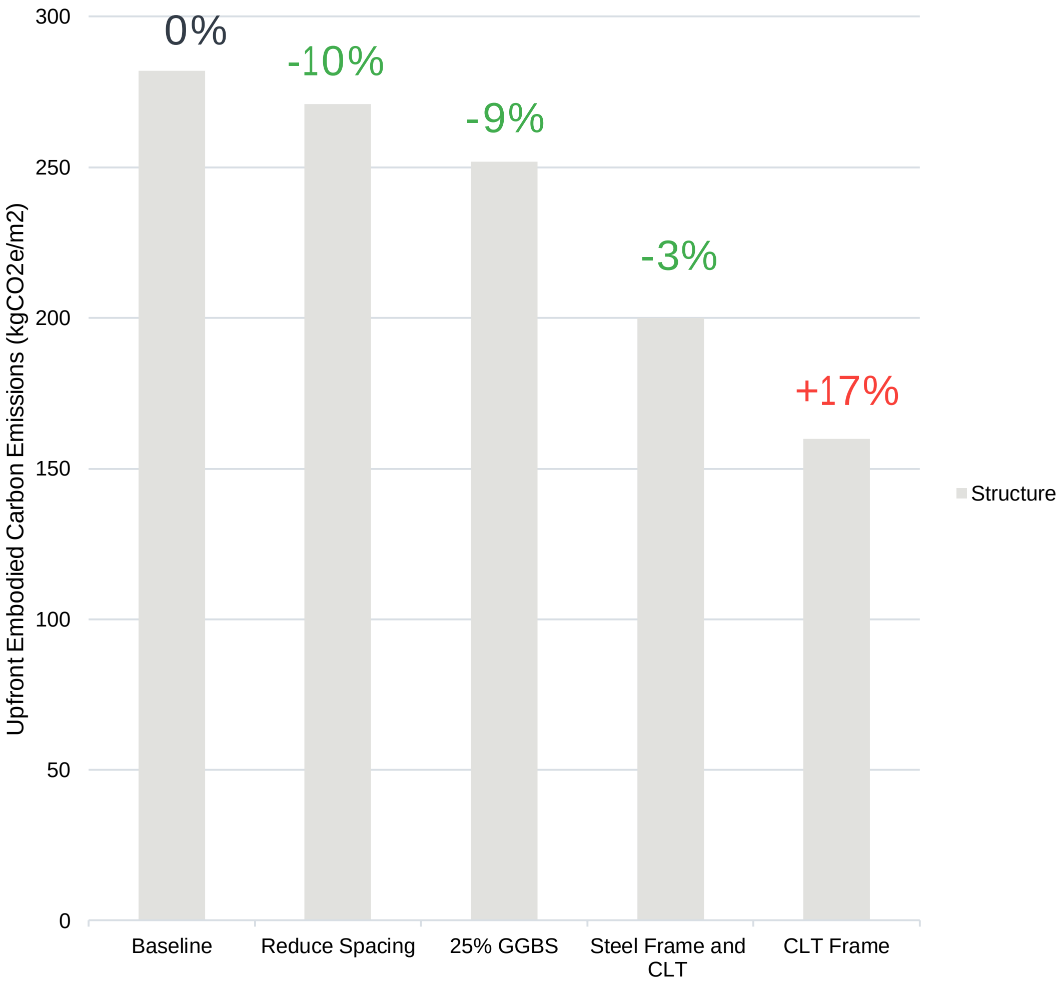
Carbon vs Cost Figures

# Mixed-use *Structure*

Baseline Total Structural Cost ~£1,500 per square metre, with % savings calculated against this structural cost.

Numbers here represent cost saving against the baseline. Each intervention is combined with the previous set of interventions for both cost and carbon. and presented as a waterfall chart.

WSP recommend reducing spans taken as a first step, before adopting other interventions such as CLT.



Carbon vs Cost Figures

# Mixed-use

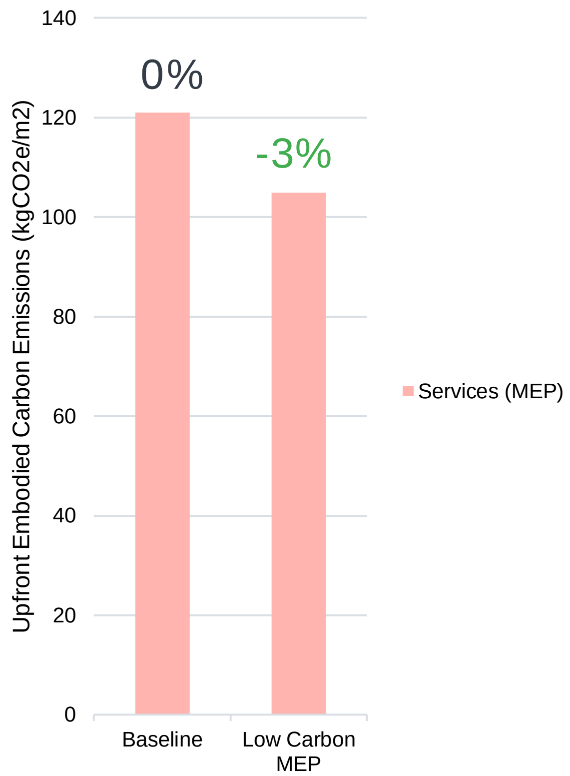
## *MEP*

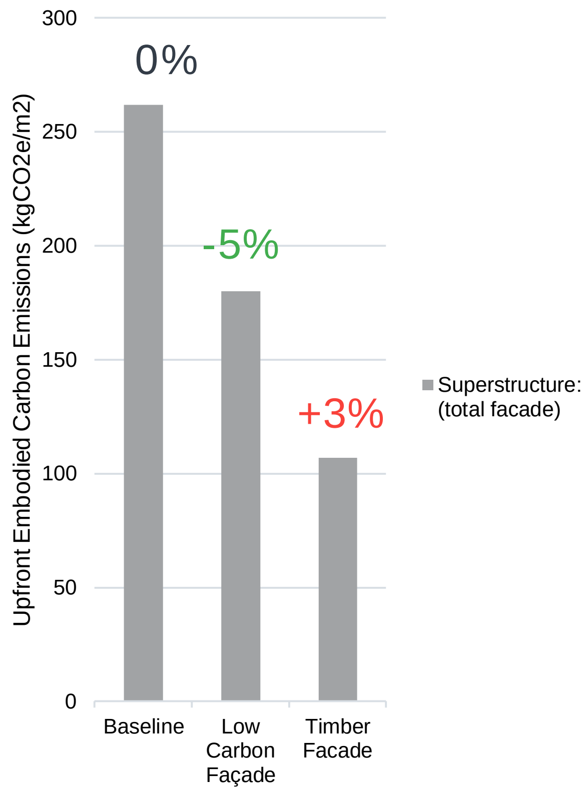
Baseline total MEP cost ~£800 per square metre, with % savings calculated against this cost. This shows both cost and carbon savings can be made by optimising MEP.

## *Facade*

Baseline total facade cost ~£500 per square metre, with % savings calculated against this cost.

The low carbon façade sees a cost reduction due to change from high cost high carbon material such as ceramic tile to brick for the opaque element, with the additional cost associated with recycled aluminium in the glazing system off set by this saving.



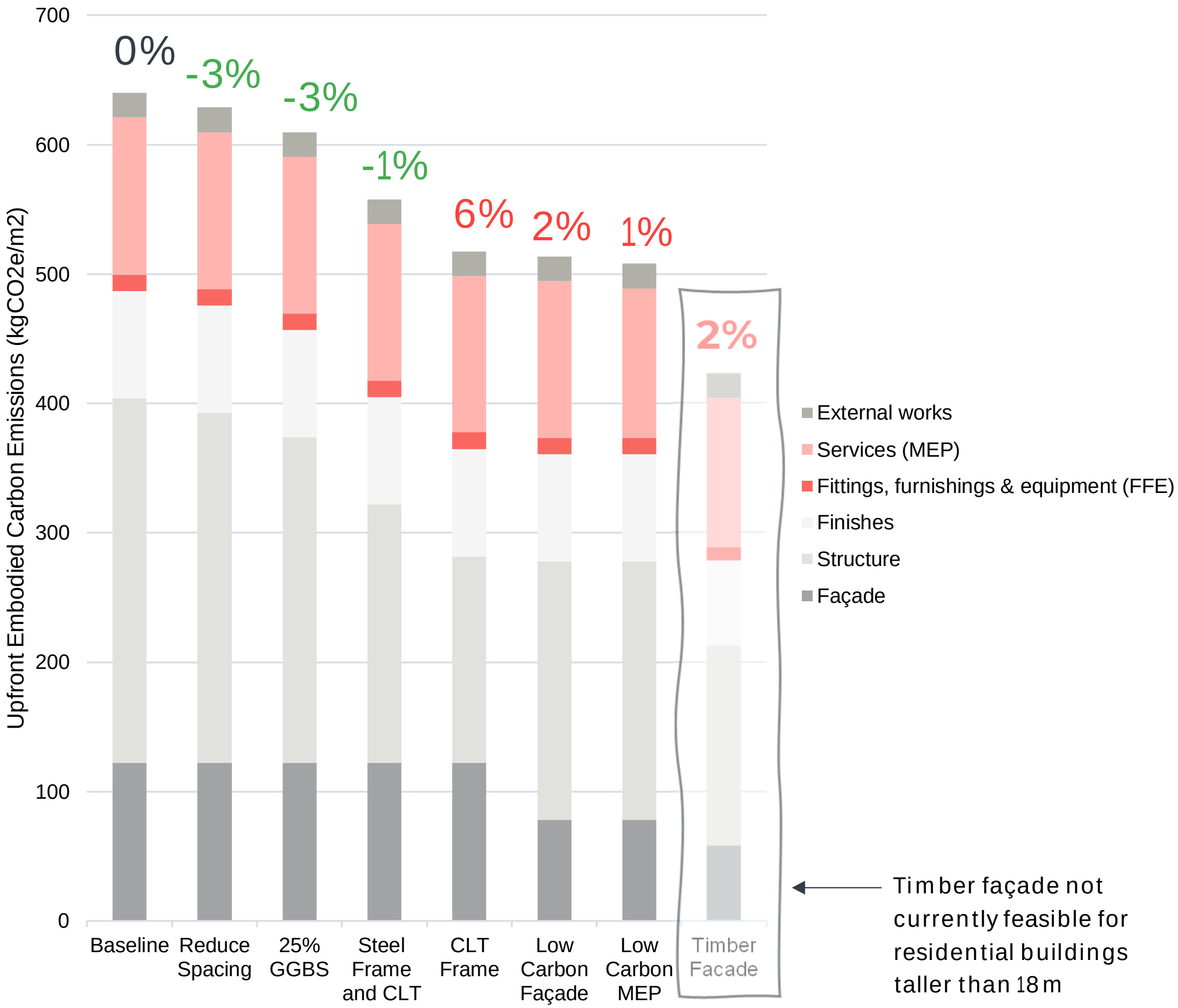



Carbon vs Cost Figures

# Mixed-use
# *All Together*

Baseline Total Building Cost ~£4000 per square metre, with % savings calculated against this notional total.

Numbers here represent cost saving against the baseline. Each intervention is combined with the previous set of interventions for both cost and carbon. and presented as a waterfall chart.




Timber façade not currently feasible for residential buildings taller than 18m

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