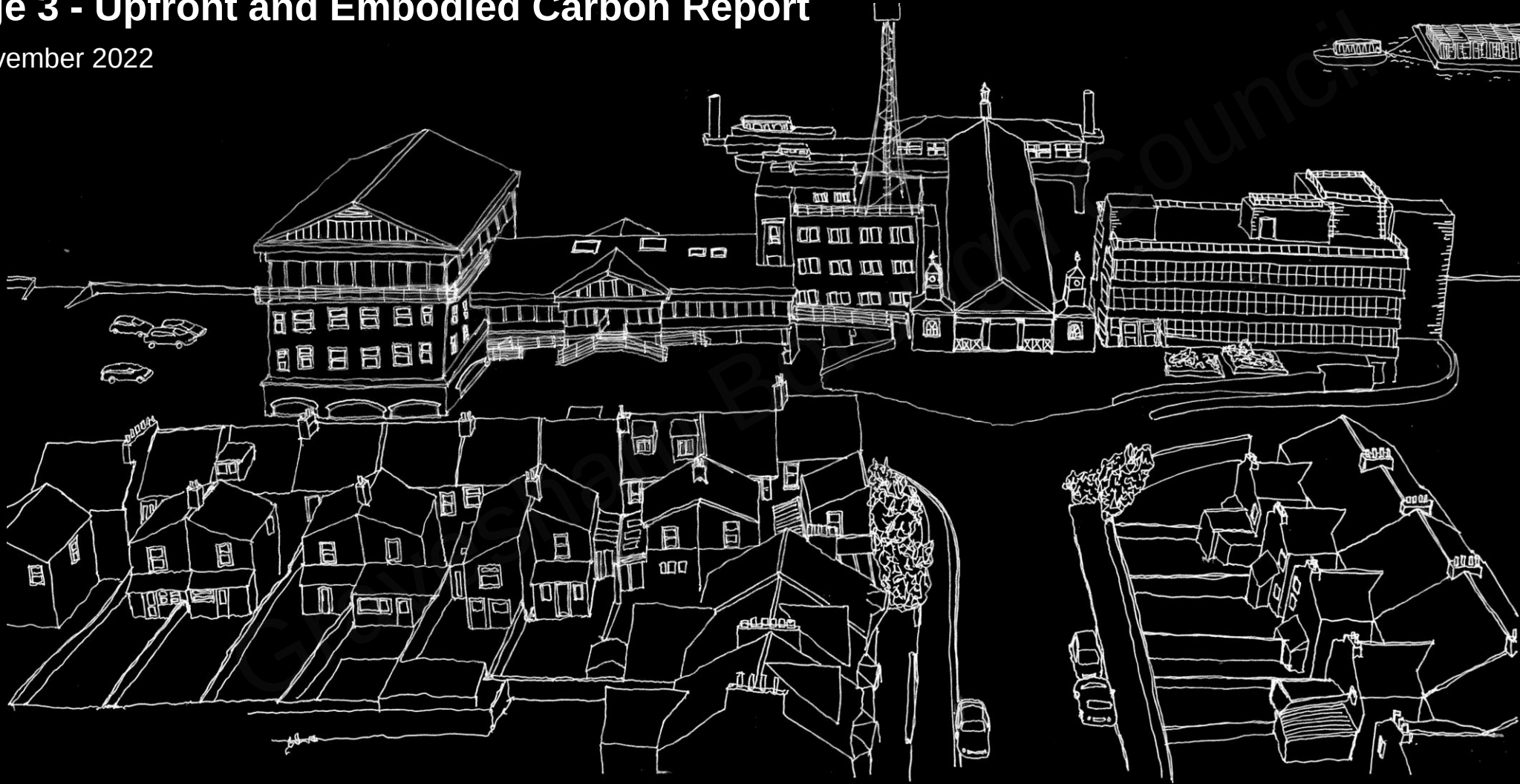


Port of London Control Centre, Gravesend

Stage 3 - Upfront and Embodied Carbon Report

8th November 2022



**BENNETTS
ASSOCIATES**

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Executive Summary

Gravesham Borough Council

Executive Summary

Port of London Authority commissioned Bennetts Associate to conduct an Embodied Carbon Study of the Port Control Centre (PCC). The following report covers upfront and embodied carbon assessment of the project at Stage 3, including carbon emissions at practical completion and projected emissions over 60 years (excluding modules B5 and B6 - operational energy and water). The study assesses PCC against the industry standard LETI rating system with the aim of achieving an A rating for upfront carbon emissions (350 kgCO₂e/m² at practical completion).

The report produces a baseline budget at Stage 3 to identify the most carbon intensive elements within the current design and develops potential carbon reduction strategies in the context of project size, location and typology. The carbon reduction strategies aim to achieve a base target of 350 kgCO₂e/m² at Practical Completion and further reductions to reach a stretch target that goes beyond the LETI A rating threshold. The final section of the report covers key actions during RIBA stages 4-6, as well as information on achieving net-zero, including carbon offsetting schemes.

Table 1. Stage 3 Carbon Budget of the PCC Building

	Baseline estimate	Reduction base target	Reduction stretch target
Practical Completion Modules A1-A5	293,929 kgCO ₂ e 375 kgCO ₂ e/m ²	280,000 kgCO ₂ e 350 kgCO ₂ e/m ²	251,364 kgCO ₂ e 321 kgCO ₂ e/m ²

Upfront Carbon equivalent at Practical Completion

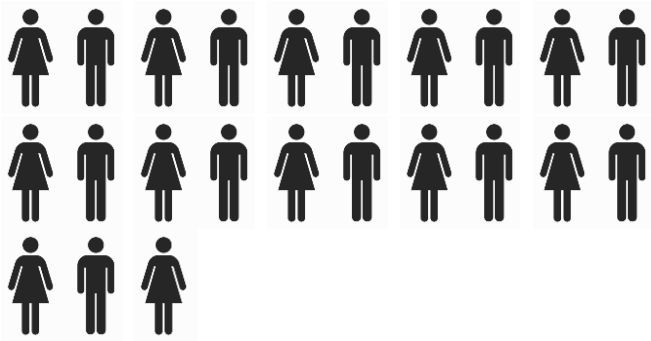
The Upfront Carbon at practical completion for the baseline scheme is 293,929 kgCO₂e – this is equivalent to:



19% of PLA's Total Emissions in 2021



24% PLA's Emissions from Vessels in 2021



Annual carbon footprint of 23 average UK residents

Project Introduction

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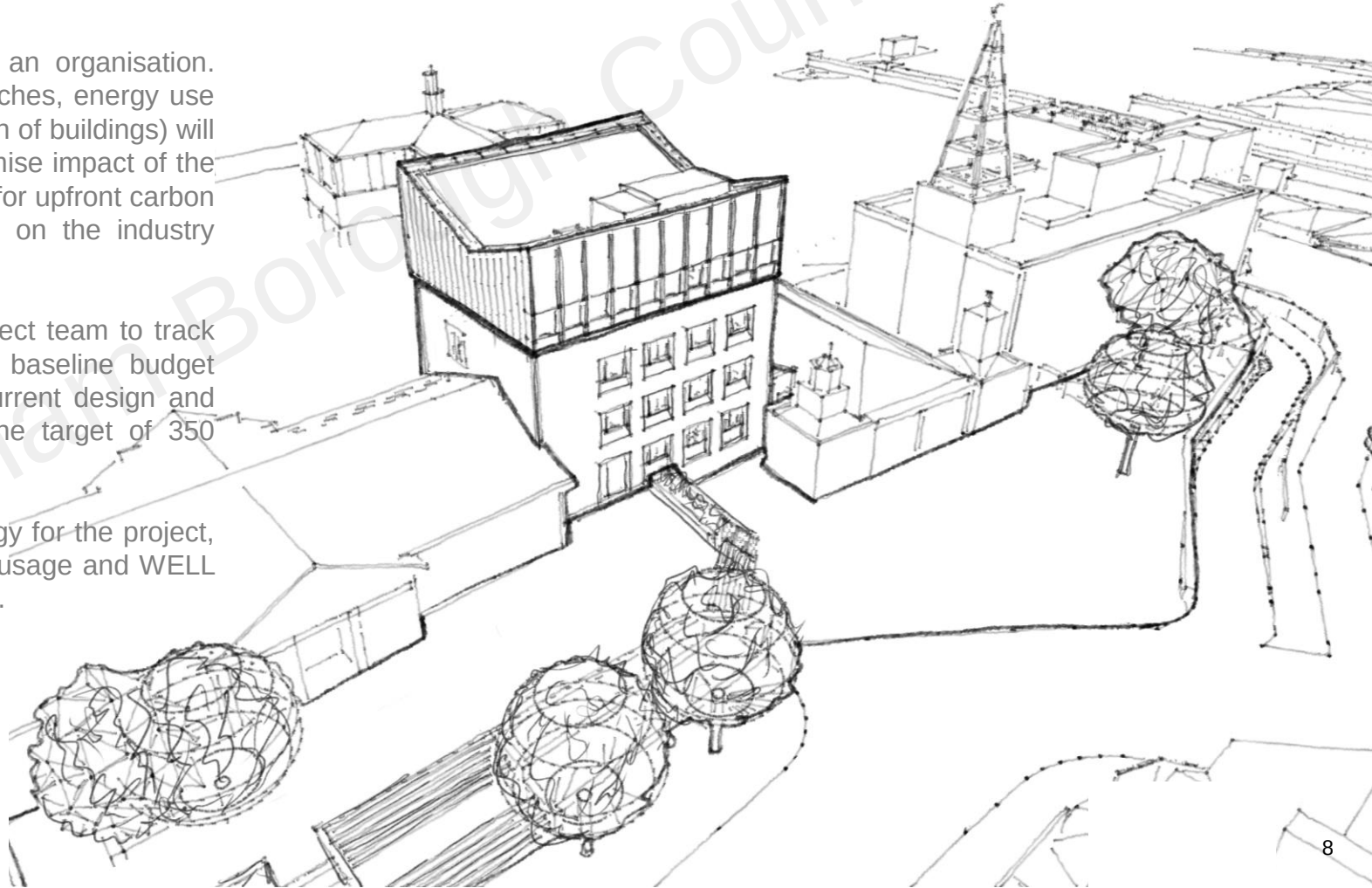
Project Introduction

The Port of London Authority's (PLA) Port Control Centre (PCC) building is situated within the PLA's London River House complex at Royal Pier Road, Gravesend. The key aims of the project are to modernise the existing PCC facility and unify the surrounding public realm and landscape in front of the PLA complex at Royal Pier Road.

Sustainability is of paramount importance to the PLA as an organisation. Following a planned change to waste/bio-fuels for pilot launches, energy use within buildings and scope 3 emissions (including construction of buildings) will become the PLA's most significant carbon footprint. To minimise impact of the PCC redevelopment, the project aims to achieve an A rating for upfront carbon emissions ($350 \text{ kgCO}_2\text{e/m}^2$ at practical completion) based on the industry standard LETI rating system.

The Upfront and Embodied Carbon analysis allows the project team to track carbon emissions throughout the project. At Stage 3 the baseline budget identifies the most carbon intensive elements within the current design and develops potential carbon reduction strategies to reach the target of $350 \text{ kgCO}_2\text{e/m}^2$.

The study is conducted as part of wider sustainability strategy for the project, alongside TM54 modelling to determine operational energy usage and WELL criteria assessment to increase health and wellbeing of users.



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Methodology

Definitions and Standards

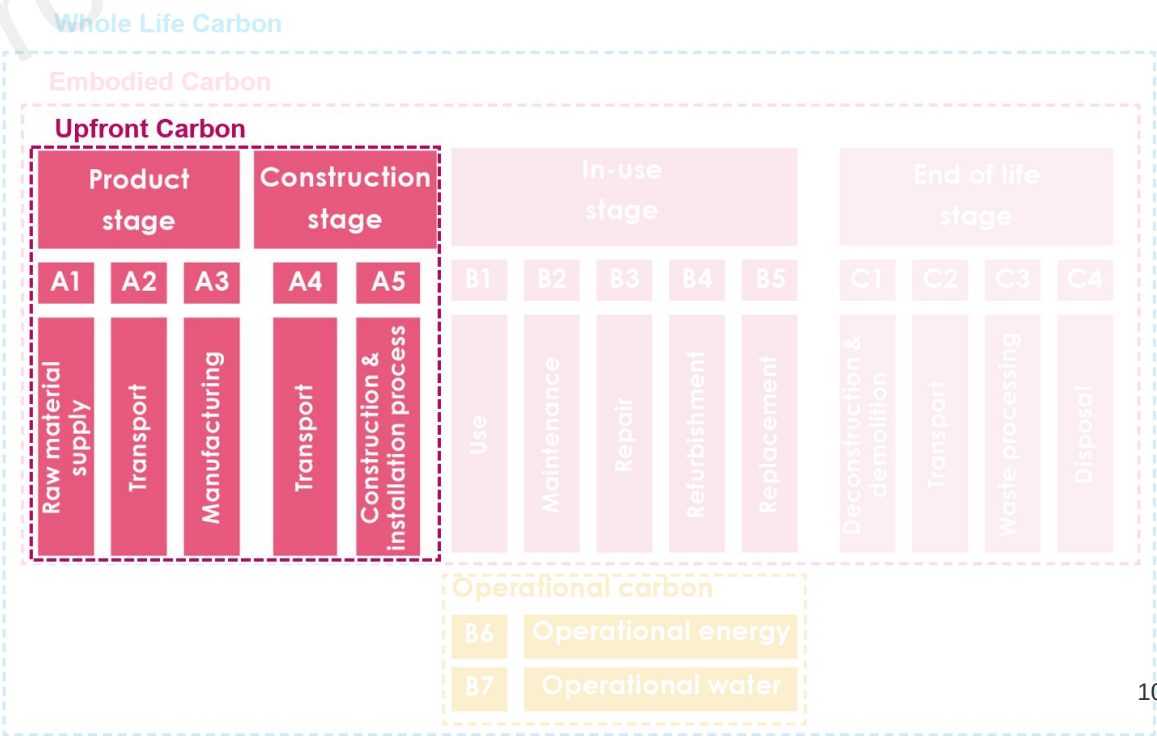
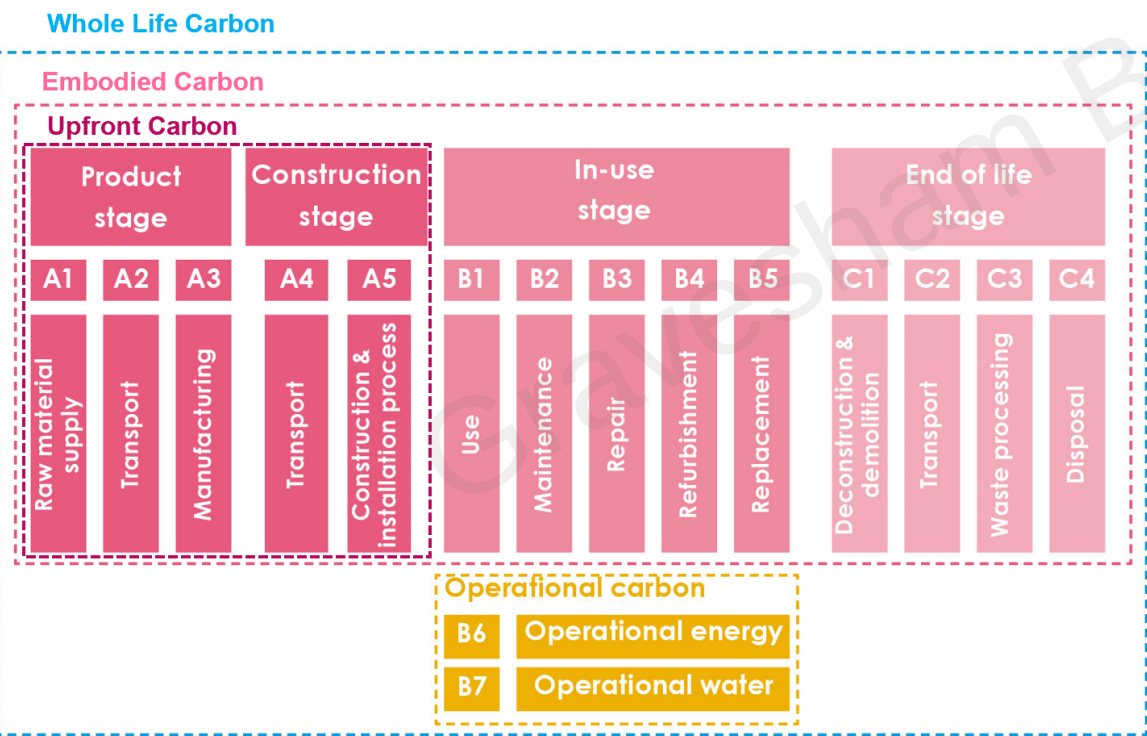
The Upfront and Embodied Carbon assessment was undertaken, with quantities and specifications based on Stage 3 architectural, structural and MEPH drawings, outline specifications, Revit models and the cost plan.

The calculations were carried out using One Click LCA software in accordance with the industry best practice RICS professional statement and LETI target alignment guides.

The standard for whole life carbon, identifies each stage in the life of a building: A - product manufacture and construction, B - in-use and C - end-of-life. Each stage is broken down into detailed modules to form a consistent methodology for carbon assessments and comparisons.

Modules A1-A3, typically reported as a single value, include the extraction and supply of raw materials, transport from the place of material extraction to a manufacturing plant and the process of turning raw resources into the construction product. **Module A4** relates to the transport of the construction product to the building site. **Module A5** represents the on-site processes needed to assemble the building, including energy used by the contractor, site operations, waste generated on site during the installation process etc.

Modules A1-A5 represent all carbon emissions up to practical completion of the building. They are often called '**Upfront Carbon**', as they represent emissions which take place before the building can be occupied similar to a capital cost.



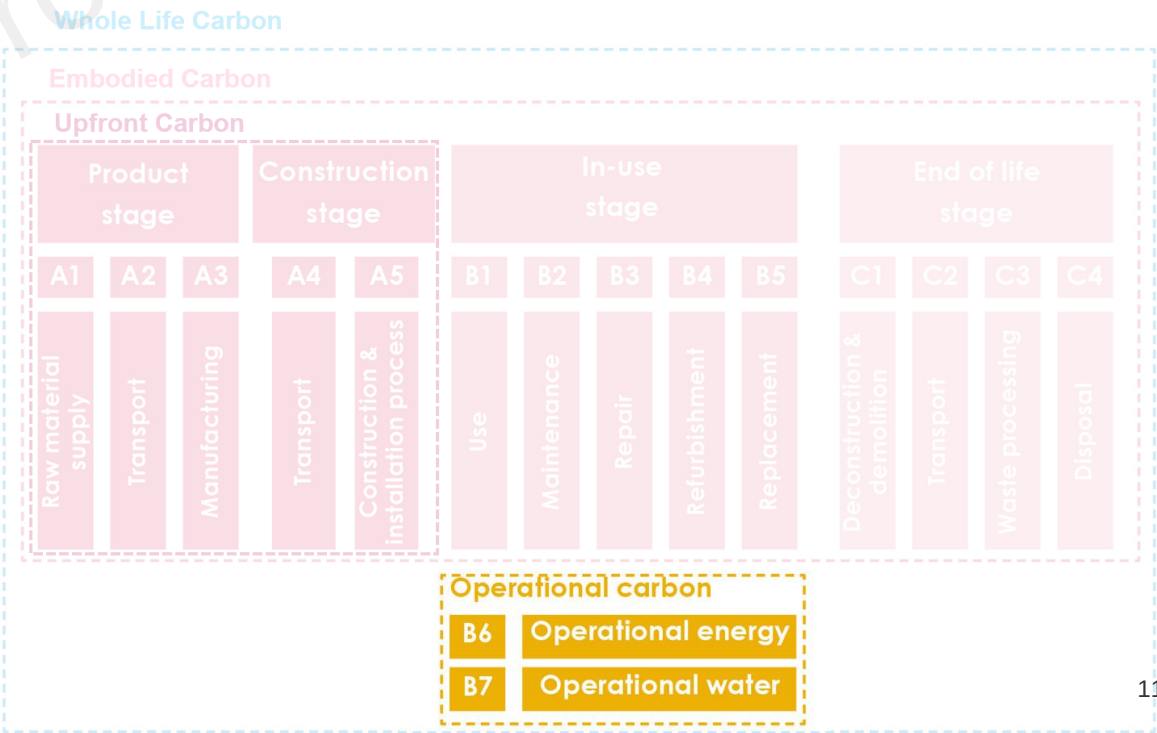
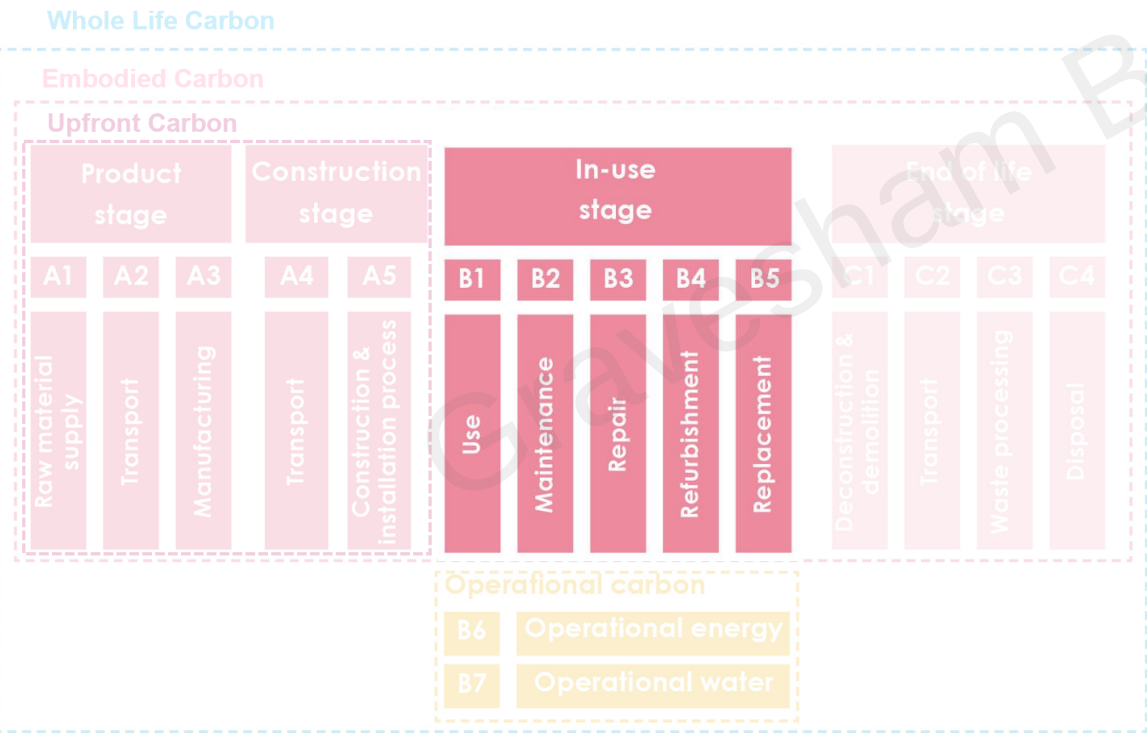
Methodology

Definitions and Standards

Modules B1-B5 cover emissions associated with maintenance, repair, refurbishment and replacement cycles. In this study stages B are estimated for 60 years after practical completion.

These emissions are related to the properties of the building materials as durable materials or components may require less maintenance and repair, and long life materials and components will need replacing less than short-life components. For example the typical life span of floor finishes are 10-15 years, hence they are assumed to be replaced 3-5 times in the 60 year period.

Modules B6 and B7 relate to use of energy and water during building occupation. Those modules are outside of the scope of this report. Predicted energy use is included in TM54 energy modelling report by HDR. This could be converted to carbon emissions with predictions for the carbon intensity of the electricity grid over time, but it is generally accepted that energy targets are a better indicator of net-zero readiness, and so typically Modules B6 and B7 are excluded from whole life figures.



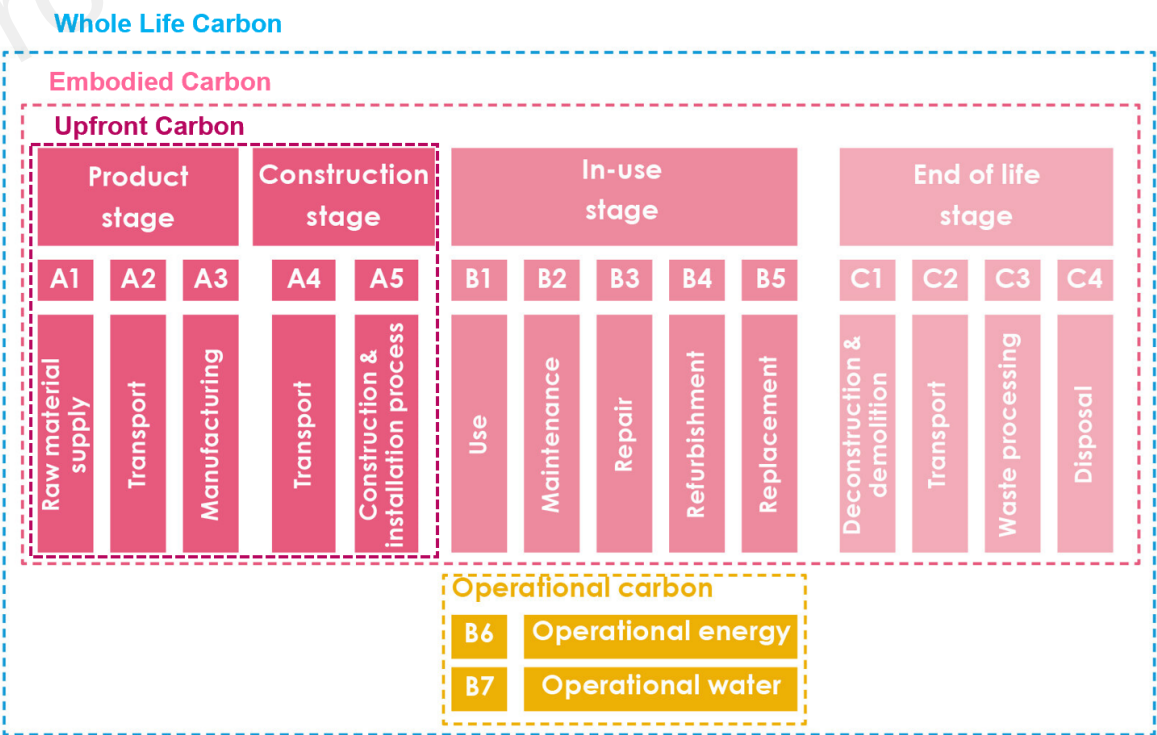
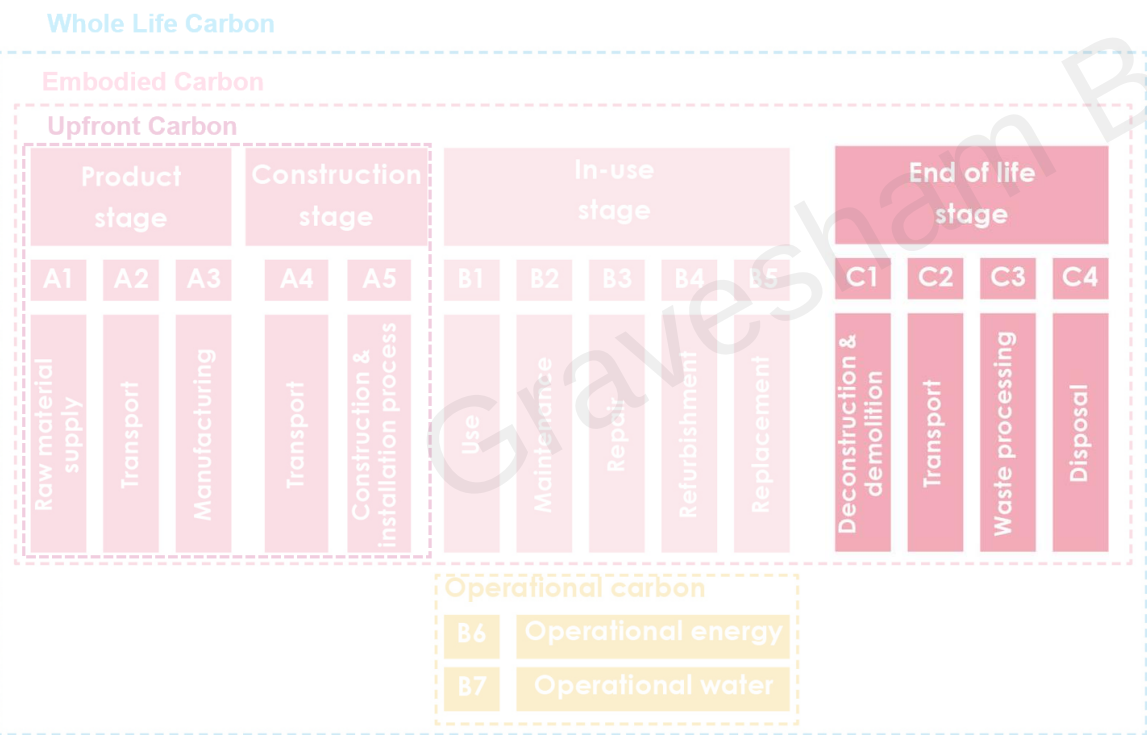
Methodology

Definitions and Standards

In the final **Modules C1-C4** represent emissions at the end of the building’s life. They represent deconstruction and demolition of its elements and the transport and processing of this waste via either landfill, recycling or reuse.

Modules A1-A5, B1-B5 and C1-C4 form the **Embodied Carbon** of the building – the carbon which is needed to build, maintain and deconstruct the building through its entire life.

The addition of **Modules B6 and B7** to the **Embodied Carbon (Modules A1-A5, B1-B5 and C1-C4)** form the **Whole Life Carbon** of the building, though this is not generally seen as a useful measurement during design stages.



Methodology

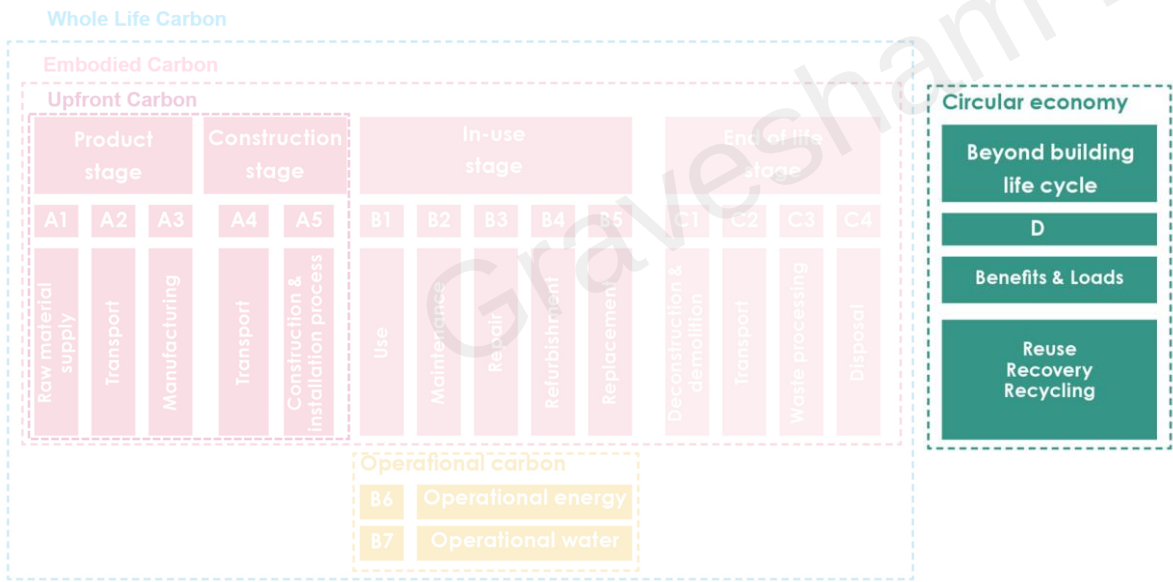
Definitions and Standards

Module D considers emissions beyond the life cycle of the PCC building, such as benefit from reuse and recycling of products that are recovered from the project. This would include reuse of a building element (for example windows) in another building after the PCC building is disassembled.

Emissions accounted for in **Module D** are excluded from any Embodied Carbon and Whole Life Carbon totals and are always reported separately. Module D is calculated due to the need for reporting, because to large amounts of uncertainty it is generally seen as the least useful metric within the carbon assessment. Other circular economy metrics and principles are more useful in maximising resource efficiency.

Sequestration stands for the carbon ‘locked’ in biogenic products during their growth. Common materials which sequester carbon are: timber, straw, hemp, cork etc. This is seen as a short term storage, helping lock away carbon during a critical period during the fight against climate change. At the end of a project’s life carbon accounting standards assume the sequestered carbon is emitted back into the atmosphere, though in reality this is unlikely to be the case beyond 2050.

In this analysis **Sequestration** is expressed as a negative number to represent carbon taken out rather than emitted. It is reported alongside, but separately to the **Upfront Carbon** (A1-A5 emissions) as it is seen as unfair to consider the sequestration without the end of life impacts. In the **Embodied Carbon** sequestration is included in the total number of modules A1-A5, B1-B5 and C1-C4, as its end of life impacts are included in the C modules.



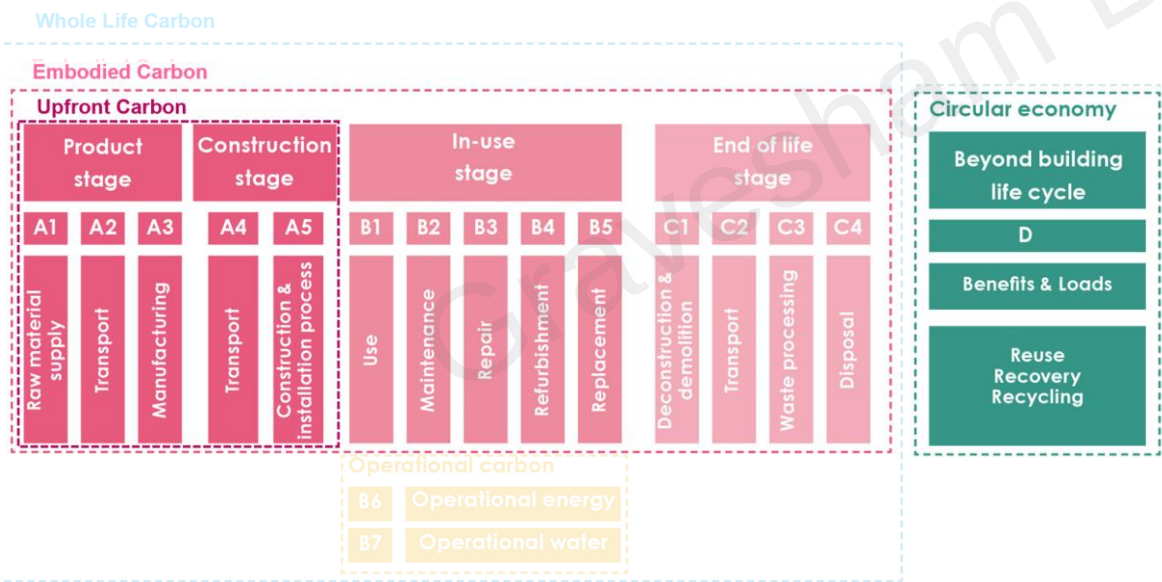
Methodology

Scope, Sources of Data and Uncertainty

The scope of the Upfront and Embodied Carbon study covers the refurbishment and extension of PCC building only, with a Gross Internal Area (GIA) of 784m². External landscape, works to relocate of comms tower from PCC to Alexandra house and minor changes to the layout of the Link Building are not included in the calculation.

This report covers the Upfront and Embodied Carbon emissions related to the building. In alignment with LETI targets it excludes external works, non-fixed FF&E and renewable energy generation (PVs), though these elements will be reviewed with the relevant consultants on a qualitative basis in future stages.

The aim is to assist the design team, contractor and client in the design and selection of materials throughout RIBA stage 2-5. Based on the current research and construction market, reasonable assumptions for stages B and C have been made. However, emissions B and C are going to happen in the future and the changing technology, industry standards and needs of the building users will have a decisive impact on the future emissions.



Due to the speculative nature of modules B and C, and the urgency of the Climate Crisis this report gives greater focus to the Upfront Carbon and strategies to minimise it. This is a fairly common industry practice, and will often correlate with reduced embodied carbon.

When estimating carbon emission at various stages of the design development it is important to use appropriate sets of data, relevant to project location and design development stage. Best practice at RIBA stage 3 is to base the calculation on average industry carbon factors, where possible specific to the UK market, which avoids overly optimistic specification assumptions and emphasises design efficiency. When no UK data is available, carbon factors from other markets are adjusted to the carbon intensity of electricity in the UK. For building materials which have no industry average, a third party verified Environmental Product Declaration (EPD) of a suitable product is used. In those cases the detailed breakdown of carbon emissions highlights that the number is dependant on a manufacturer.

Overall the certainty of any upfront and embodied carbon estimate is dependant on the state of industry research and available data. It is important to highlight that the level of information on the upfront and embodied carbon of specific MEPH elements is currently limited. This analysis is based on average industry values for various services sub-categories specific to the office typology. However, due to the lack of data available for specific equipment the MEPH upfront and embodied carbon is likely to be less accurate than other elements. Nonetheless, inclusion of services provides a helpful estimation of the emissions and highlights a need for further studies in future stages and more industry research.

Another area of uncertainty is material quantities. At RIBA stage 3 the majority of building materials can be accurately estimated, but there are specialist elements and product which require input from contractor and/or manufacturer such as curtain wall systems. For those building elements, where material quantities may change as the design develops, conservative estimates have been used. Most significant areas of uncertainty are highlighted in the Upfront Carbon Analysis section of this report.

Baseline Carbon Estimate

Gravesham Borough Council

Baseline Carbon Estimate

Breakdown between building elements

Table 2. shows a Baseline Carbon Estimate for the building design at Stage 3. It is broken down into industry standard building categories. Numbers are shown as absolute carbon and intensity carbon (values per m² of the GIA). The Baseline Carbon at the early design stages is estimated using average, generic or typical carbon factors. This factors in the limited availability of low carbon material alternatives, uncertainty of unspecified building elements and limited control over the contractor's and subcontractor's material procurement and data transparency. Importantly it also focuses the conversation on the efficiency of material use, before moving on to specification choice in Stage 4. As the project will report carbon at key stages, including tender, technical design and completion, the data accuracy will increase as the design and specification becomes increasingly more certain.

As part of the project brief design team has established the Upfront Carbon target for the project. The following sections of this report will assess how the baseline scenario performs against the Upfront Carbon target, highlight carbon 'hot spots' (elements with the most impact on the overall carbon value) and detail uncertainty and variation in carbon values between specific products.

Table 2. Breakdown of Upfront and Embodied Carbon at Stage 3

Category	Total Upfront Carbon A1-A5 (kgCO ₂ e)	Upfront Carbon per m ² A1-A5 (kgCO ₂ e/m ²)	Sequestration (kgCO ₂ e)	Sequestration per m ² (kgCO ₂ e/m ²)	In Use B1-B5 (kgCO ₂ e)	Life Span (years)	End of Life C1-C4 (kgCO ₂ e)	Total Embodied Carbon A-B-C incl Seq. (kgCO ₂ e)	Embodied Carbon per m ² A-B-C incl Seq. (kgCO ₂ e/m ²)	Beyond Building Life Cycle D (kgCO ₂ e)	Beyond Building Life Cycle per m ² D (kgCO ₂ e/m ²)
1 Substructure	12,700	16	0	0	0	>60	146	12,846	16	-1,019	-1
2.1 Frame	42,422	54	-12,373	-16	0	>60	636	30,685	39	-28,337	-36
2.2 Upper Floors	7,954	10	0	0	0	>60	128	8,082	10	-891	-1
2.3 Roof	7,664	10	-6,023	-8	4,913	35-60	83	6,637	8	-4,688	-6
2.4 Stairs & Ramps	15,986	20	0	0	0	>60	228	16,214	21	-10,269	-13
2.5 Ext. Walls	36,588	47	-18,615	-24	34,003	35	347	52,324	67	-33,087	-42
2.6 Windows & Ext. Doors	13,145	17	-1,001	-1	12,648	35	122	24,915	32	-334	0
2.7. Int. Walls & Partitions	34,962	45	-3,748	-5	50,213	20	212	81,639	104	-4,528	-6
2.8 Int. Doors	4,050	5	-1,012	-1	6,501	20	47	9,587	12	-152	0
3.1 Wall Finishes	700	1	-314	0	2,772	10-35	1	3,159	4	-2,259	-3
3.2 Floor Finishes	39,449	50	-17,694	-23	77,158	10-36	5,373	104,286	133	-74,567	-95
3.3 Ceiling Finishes	13,289	17	-5,961	-8	16,960	10-37	101	24,390	31	-17,439	-22
4 Fittings, furnishings & equipments	1,495	2	0	0	639	10	1	2,135	3	0	0
5 Services (MEP)	60,059	77	0	0	112,870	15-25	261	173,190	221	-34,240	-44
7 Existing bldg	3,465	4	0	0	0	>60	0	3,465	4	0	0
TOTAL kg CO ₂ e kg CO ₂ e	293,929	375	-66,741	-85	318,679		7,688	553,555	706	-211,810	-270

Building elements
defined by RICS methodology and LETI Carbon Targets Alignment

Upfront Carbon Modules A1-A5
the extraction and supply of raw materials, transport from place of material extraction to a manufacturing plant and the process of turning raw resources into the construction product; transport of the product to the building site and on-site processes needed to assemble the building
Sequestration is not counted within this total as per industry best practice.

Sequestration
the carbon 'locked' in biogenic products during their growth.

Modules B1-B5
the emissions associated with maintenance, repair, refurbishment and replacement cycles. In this study stages B are estimated for 60 years after practical completion. The **Life Span** column shows the amount of years before given building element needs to be replaced on average (this is specific to each component in the calculation).

Modules C1-C4
represent emissions at the end of the building's life - deconstruction and demolition of its elements, transport of waste and dismantled elements from building site to landfill, recycling facility or another building site where they can be reused

Total Embodied Carbon value includes Models A1-A5, B1-B5 and C1-C4 as well as Sequestration

Module D considers emissions beyond the life cycle of the PCC building, such as benefit from reuse, recovery and recycling of products. This is not easily comparable and is only included for best-practice reporting.

Carbon Targets

LETI Carbon Alignment metric and project targets

Carbon targets for the PLC PCC project are defined within the **LETI Carbon Alignment Matrix**. The LETI rating system was developed to provide alignment in Embodied Carbon measurement and comparison across the industry and allow for comparisons between projects and sectors. This methodology was produced together with RIBA, the GLA, IStructE and the UKGBC with Bennetts Associates playing a large role in its development. It is considered the interim step towards developing net zero carbon targets that reflect the UK’s carbon budget.

The matrix is based on a letter rating system, similar to the Display Energy Certificates or energy efficiency rating of consumer electronics. It allows industry professionals to talk about an “A rated” building and recognise a consistent level of ambition regardless of the project or sector. 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 over demolition.

There are currently 4 typology rating bands: Office, Residential, Education and Retail. The closest match to the function of the Port Control Centre is ‘Office’ and targets for project will be set within the ‘Office’ category. Nonetheless, the differences between the character of VTS Operations and a typical office block are acknowledged. The main variations occur due to: 24h operation of VTS personnel, increased equipment needed for VTS and specific desk layout to improve ergonomics, which are more likely to influence operational energy targets than upfront and embodied carbon targets.

The current industry average is set at rating E: <950kgCO₂e/m² at Practical Completion (Upfront Carbon). The current best practice is considered to be rating C: <600kgCO₂e/m² upfront carbon. Rating B and above is considered a robust stretch target with an A rating considered to be equivalent to aligned with net-zero by 2030.

The Port of London Authority has developed a robust strategy for decarbonizing its operations which fall into scope 1 and 2 emission categories. Soon Scope 3 may become PLA’s most significant source of emissions, as all building redevelopments including Port Control Centre fall in the Scope 3 emissions category the project aims to align with the PLA’s ambition to minimise its carbon impacts. Therefore the **base target for the Port Control Centre project is set at a LETI A rating for Upfront Carbon (<350 kgCO₂e/m²) within the Office category.**

Embodied Carbon emissions for stages beyond practical completion are reliant on building owner’s actions as well as the deconstruction process at the end of building’s life. Due to lack of control over this future the design team will analyse and measure Embodied Carbon throughout all stages of the project but will not set a specific target, and will focus on reductions relating to Upfront Carbon. This is however still likely to reduce Embodied Carbon.

Table 3. LETI Rating Matrix for Upfront Carbon, A1-A5 (exc. Sequestration)

Band	Office
A++	<100
A+	<225
A	<350
B	<475
C	<600
D	<775
E	<950
F	<1100
G	<1300

Project target
350 kgCO₂e/m²

Current best practice
600kgCO₂e/m²

Current industry average
950kgCO₂e/m²

Table 4. LETI Rating Matrix for Embodied Carbon, A1-A5, B1-B5, C1-C4 (inc. Sequestration)

Band	Office
A++	<150
A+	<345
A	<530
B	<750
C	<970
D	<1180
E	<1400
F	<1625
G	<1900

Current best practice
970kgCO₂e/m²

Current industry average
1400kgCO₂e/m²

Carbon Targets

Progress against project target

At the end of Stage 3, the baseline carbon estimate is 375kgCO₂e/m² at practical completion and 706kgCO₂e/m² over the whole life of the building assuming a 60 year life. Even though the baseline carbon total is just above the project target, it is significantly lower than current industry average and best practice projects.

The baseline calculation considers average and generic material specifications, leaving room to improve the carbon emissions by selecting products with lower environmental impact and by optimising the quantities of the material. The following sections of the report will analyse the most carbon intensive building elements and the potential for carbon reductions to meet the project target.

Table 5. LETI Rating Matrix for Upfront Carbon, A1-A5 (exc. Sequestration)

Band	Office
A++	<100
A+	<225
A	<350
B	<475
C	<600
D	<775
E	<950
F	<1100
G	<1300

Project Baseline
375 kgCO₂e/m²

Project target
350 kgCO₂e/m²

Current best practice
600kgCO₂e/m²

Current industry average
950kgCO₂e/m²

Table 6. LETI Rating Matrix for Embodied Carbon, A1-A5, B1-B5, C1-C4 (inc. Sequestration)

Band	Office
A++	<150
A+	<345
A	<530
B	<750
C	<970
D	<1180
E	<1400
F	<1625
G	<1900

Project Baseline
706 kgCO₂e/m²

Current best practice
970kgCO₂e/m²

Current industry average
1400kgCO₂e/m²

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Upfront Carbon Analysis

Breakdown between building elements

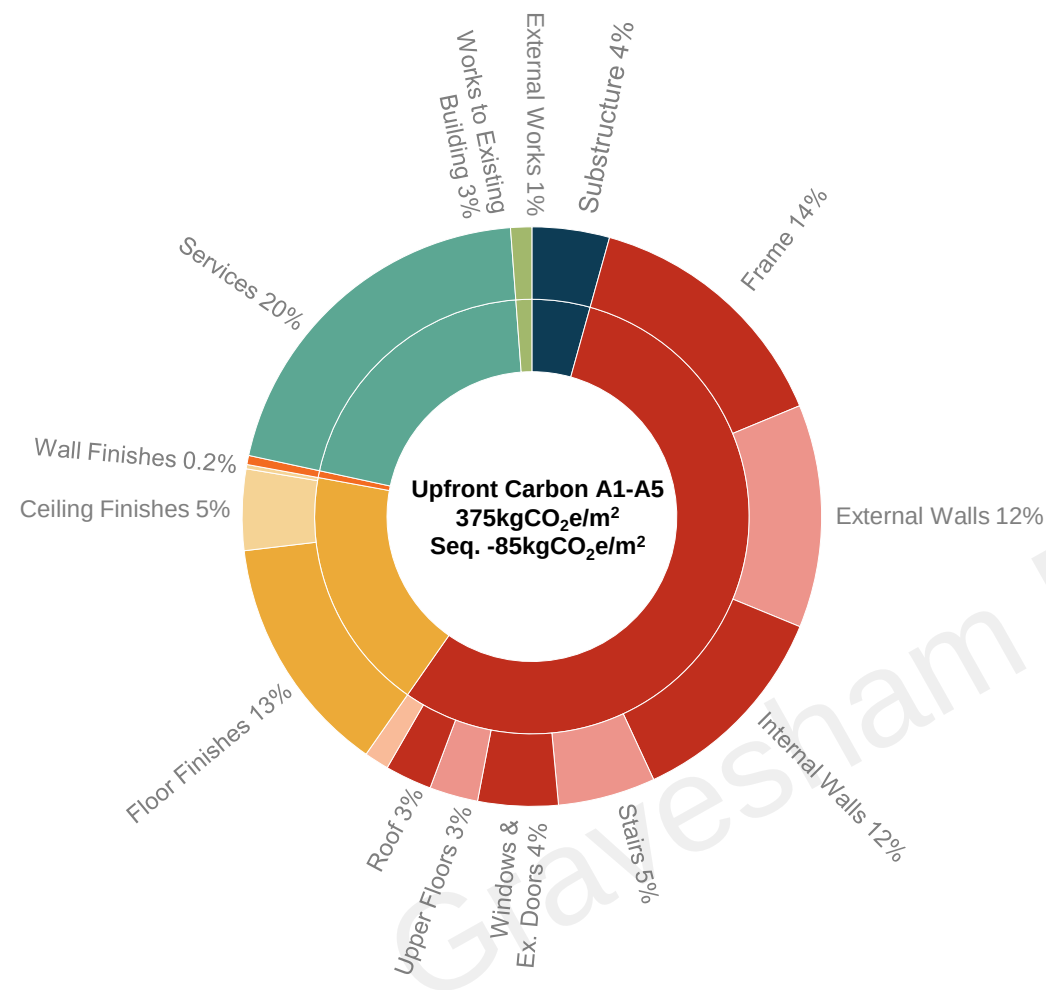


Figure 1. Overview of Upfront Carbon breakdown between all building elements at Practical Completion (modules A1-A5)

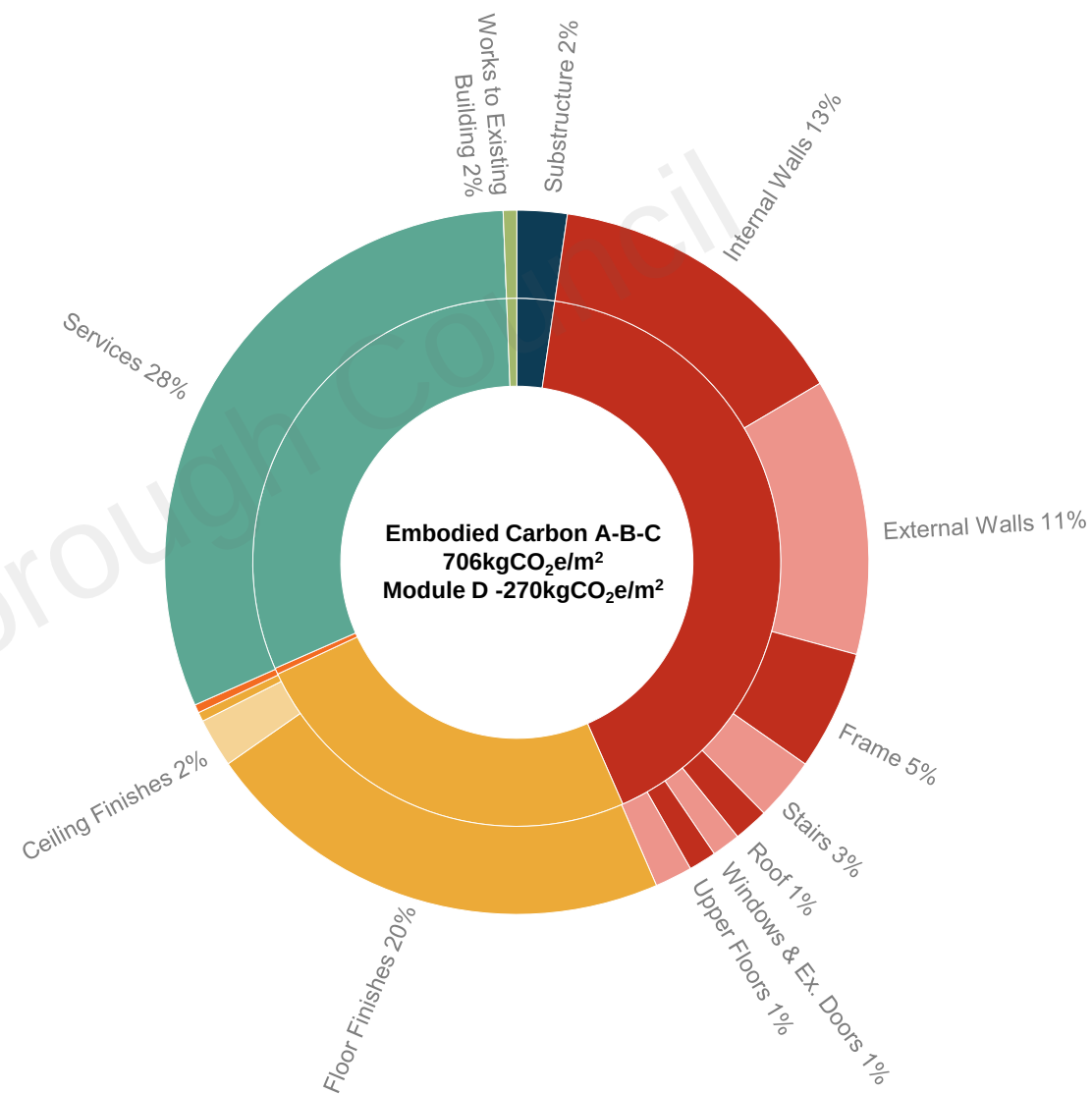


Figure 2. Overview of Embodied Carbon breakdown between all building elements over whole life of the building assuming a 60 year lifespan (modules A-C, excluding B6 and B7).

Variation in proportions between Upfront and Embodied Carbon of some building elements occurs due to their maintenance, frequency of replacement and measured needed to dispose or recycle them at the end of life as well as carbon sequestered by some of the materials.

Upfront Carbon Analysis

Comparison with industry average

Figures 1 and 3 present a breakdown of the upfront carbon between various building elements of the PLA PCC baseline scenario and an average office building. There is limited data available for the detailed breakdown of various elements of superstructure and finishes, but typically the building elements which contribute the most to the overall upfront carbon value are: substructure, frame, external walls and services.

The baseline carbon estimate for the PCC design is less than half of the upfront carbon of an average project. As a result, building elements which retain similar percentage of the total value have in fact half of the average carbon emissions associated to them. Examples of that are external walls and services.

External walls typically represent around 16% of the overall carbon and 12% in the baseline total for the PCC building. This means that the amount of carbon associated with external walls in the PCC project has decreased proportionally to the overall decrease in carbon. The main reason for decreased emission are retention of existing brick walls and selection of light weight render as a finish. The highest contribution to the external walls emissions is the aluminium cladding on the top floor extension.

Services typically cover 15% of the overall carbon value, in the baseline PCC total services cover 20% of the total number. Similarly to the external walls, the amount of carbon associated with services in the PCC project has decreased proportionally to the overall decrease in carbon. Again, the main reason for decreased emission is retention of some of the plant equipment (e.g. generator - usually some of the most carbon intensive building elements). It is important to keep in mind that typical lifespan of services is shorter than the lifespan of structural elements and it can not be extended in the same way as structure can (for example by strengthening of columns or foundations). Moreover, to minimise operational energy of the building it is essential to upgrade outdated services with more efficient components. In the case of the PCC building there is currently no mechanical ventilation which is one of the most carbon intensive elements of the building, but is a key requirement in achieving the brief.

The building element which has decreased the most in comparison to the average office building is **substructure**. This is due to the fact that vast majority of foundations are retained and do not require strengthening.

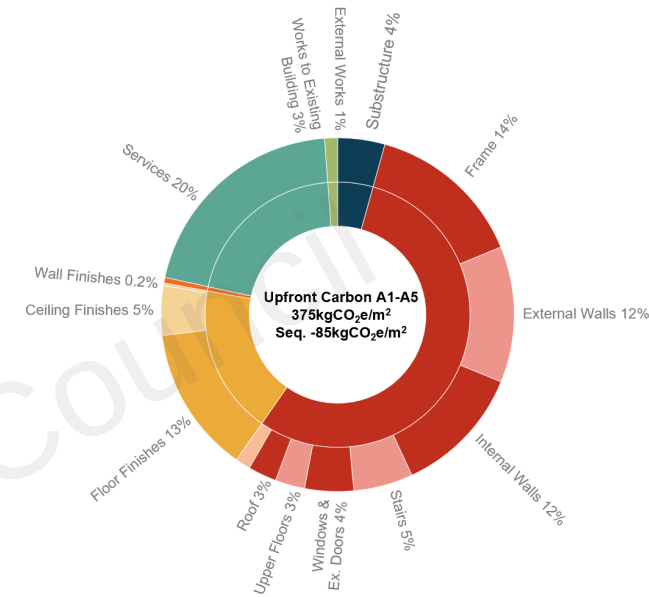


Figure 1. Overview of Upfront Carbon breakdown between all building elements at Practical Completion (modules A1-A5)

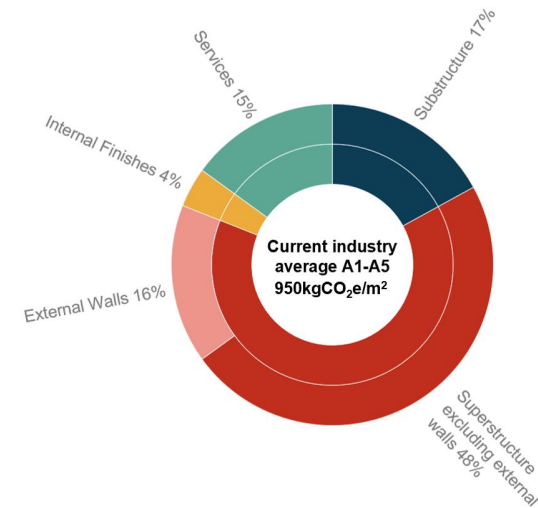


Figure 3. Typical breakdown between building elements at Practical Completion (modules A1-A5) for an average office building based on LETI Carbon Primer (p.26)

Upfront Carbon Analysis

Comparison with industry average

Although not represented separately in the breakdown of an average office building **frame** is typically one of the most significant contributors to the overall upfront carbon of a project. The PCC design retains majority of the existing structure. However, the new steel structure of the core adds a significant amount of carbon to the total carbon number.

The breakdown of the PCC baseline total also reveals that **internal walls** are one of the most significant contributors to overall carbon. The current design breaks the space into smaller rooms and incorporates a relatively high proportion of fire rated walls in comparison to non-fire rated partitions. Plasterboard and metal studs, used in fire rated partitions, are typically carbon intensive products, and as other elements have reduced due to retention, these have increased. It's also worth noting that most data for typical offices is based on large speculative office buildings with a small amount of internal sub-division.

Finally, the impact of **internal finishes** becomes proportionally more significant against the total carbon number. On an average project the amount of carbon associated with structure, external walls and services is so large that finishes become relatively small. Since large amount of structure, external walls and some services are retained the shift in significance towards internal finishes was expected. The specification and amount of internal finishes is considered in more detail in the following sections of this report.

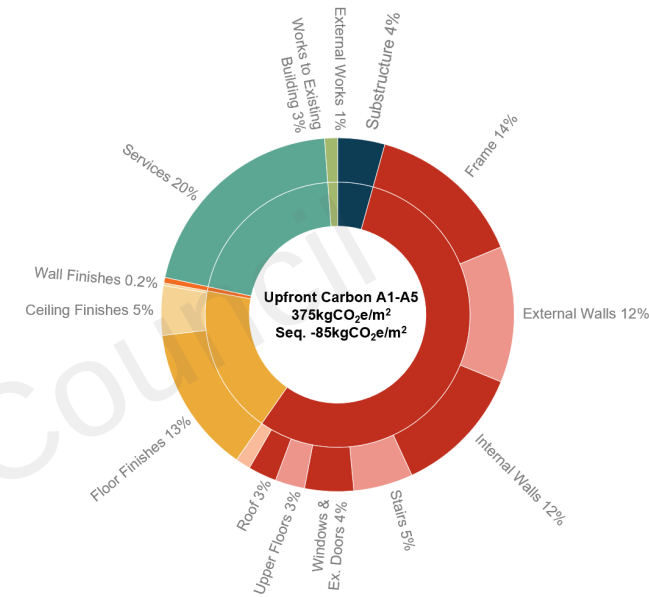


Figure 1. Overview of Upfront Carbon breakdown between all building elements at Practical Completion (modules A1-A5)

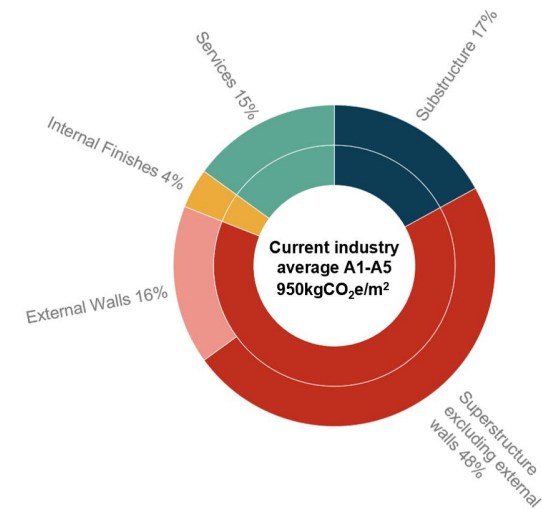


Figure 3. Typical breakdown between building elements at Practical Completion (modules A1-A5) for an average office building based on LETI Carbon Primer (p.26)

Upfront Carbon Analysis

Breakdown of Baseline Carbon estimate between building elements

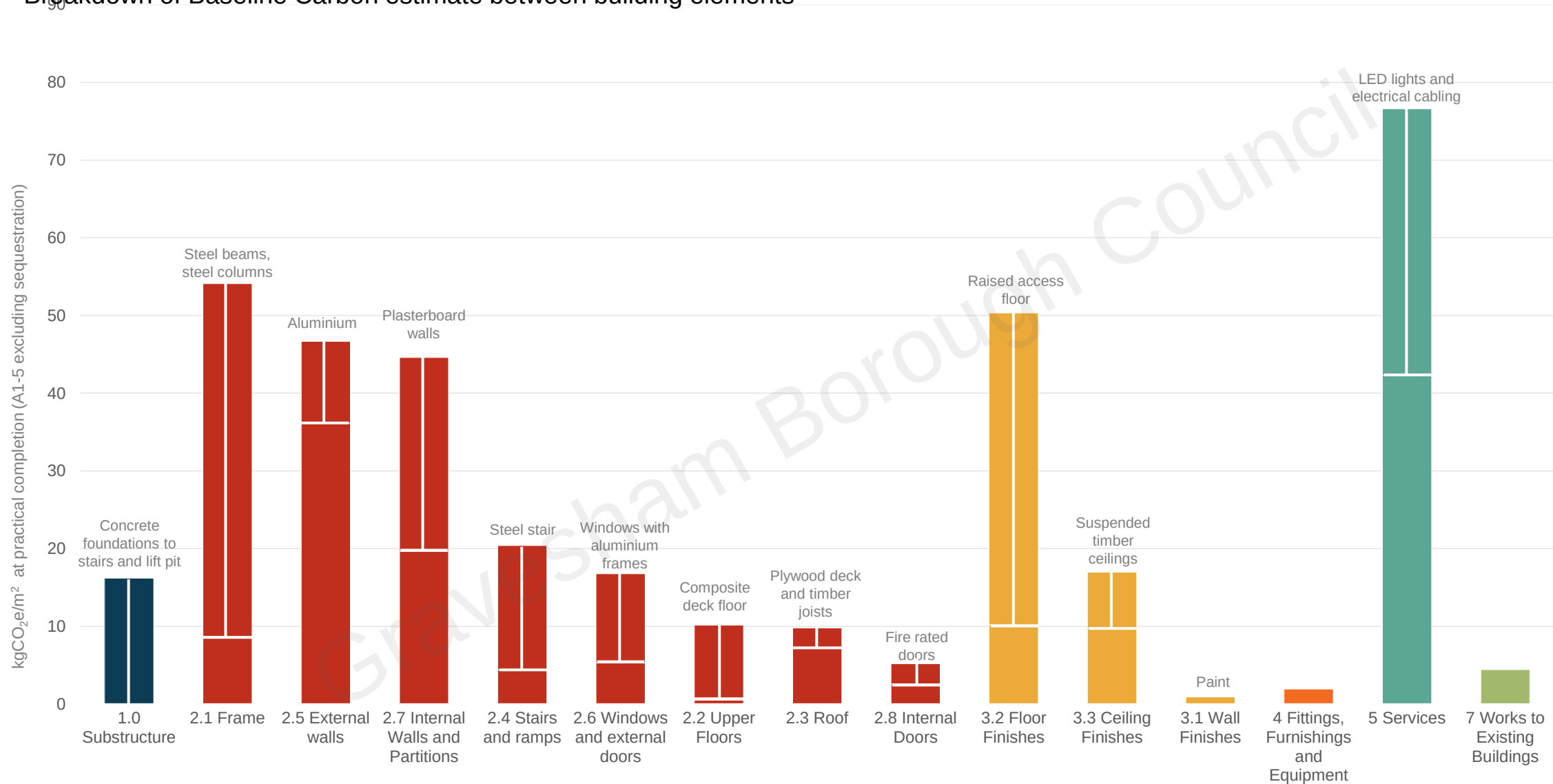


Figure 4. Overview of Upfront Carbon per m² of all building elements at Practical Completion (modules A1-A5). Building materials with highest contribution are listed on the chart. Their contribution is marked against total emissions for each category.

Potential Carbon Reductions

List of key building elements and carbon ‘hot spots’

Table 7. Breakdown of carbon emissions of key building elements, potential material alternatives and resultant carbon reductions.

No.	Resource	Upfront Carbon A1-A5 (kgCO ₂ e)	Upfront Carbon A1-A5 (% of entire building)	Sequestration A1-A5 (kgCO ₂ e)	Data certainty	Alternative Resource	Alternative Upfront Carbon A1-A5 (kgCO ₂ e)	Potential change of Upfront Carbon of the Building Element A1-A5 (%)	Potential change of Upfront Carbon of the Entire Project A1-A5 (%)	Next stage
1 Substructure										
	Ready-mix concrete, normal strength, generic, C32/40, 30% GGBS content in cement and reinforcement steel, 97% recycled content	13,405	5%		Market Average	30% GGBS content in cement increased to 70% GGBS	11,825	-12%	-0.5%	Update specification and tender requirements. Select contractor able to deliver higher GGBS content
2.1 Frame										
	Structural steel profiles, generic, 20% recycled content, S355	28,854	10%		Market Average	Structural steel profiles, generic, 40% recycled content, S355	26,672	-8%	-0.7%	Update specification and tender requirements. Select contractor able to deliver higher recycled content. Typically recycled content of steel in the UK is around max 35%. Sourcing of steel with higher recycled content might prove challenging.
	Structural hollow steel sections, generic, 20 % recycled content, circular, square and rectangular profiles, S355	6,962	2%		Market Average	Structural hollow steel sections, generic, 30 % recycled content, circular, square and rectangular profiles, S355	6,604	-5%	-0.1%	Update specification and tender requirements. Select contractor able to deliver higher recycled content. Typically recycled content of steel in the UK is around max 35%. Sourcing of steel with higher recycled content might prove challenging.
	Glued laminated timber	5,147	2%	-12,373	Market Average	Manufacturer specific alternatives available				For further reduction review manufacturer specific emissions and location of the factory.
	Ready-mix concrete, normal strength, generic, C32/40, 30% GGBS content in cement and reinforcement steel, 97% recycled content	551	0%		Market Average	30% GGBS content in cement increased to 50% GGBS	515	-6%	-0.01%	Update specification and tender requirements. Select contractor able to deliver higher GGBS content
2.2 Upper Floors										
	Composite deck floor: 30% GGBS content in cement, reinforcement steel and steel sheet with 90% recycled content	7,572	3%		Market Average	30% GGBS content in cement increased to 70% GGBS	6,192	-18%	-0.5%	Update specification and tender requirements. Select contractor able to deliver higher GGBS content. Maintain 90% recycled content in steel products
	Composite deck floor: 30% GGBS content in cement, reinforcement steel and steel sheet with 90% recycled content	7,572	3%		Market Average	Hollow core, pre-cast concrete slabs with 30% GGBS replacement				Potential carbon saving. The alternative floor structure to be discussed with Structural Engineer before accurate carbon assessment can be made
2.3 Roof										
	Hot-dip galvanized steel sheets with zinc coating, 15% recycled content	964	0%		Market Average	Small amount of carbon in comparison to other element. Manufacturer specific alternatives available				For further reduction review manufacturer specific emissions.
	Bitumen-polymer membrane roofing, 2 layer, fully torched	746	0%		Market Average	Small amount of carbon in comparison to other element. Manufacturer specific alternatives available				For further reduction review manufacturer specific emissions.
	Roof above link to Pier	544	0%		Market Average	Retain structure above	0	-100%	-0.2%	Subject to site survey, it might be impossible to retain the slab
	Plywood and timber joist roof structure	2,050	1%	-6,023	Market Average	100mm CLT roof slab	5,071	147%	1.0%	Plywood and timber joist roof structure reduces carbon by 50% in comparison to CLT slab
2.4 Stairs & Ramps										
	Stair - structural steel profiles, 20% recycled content,	12,529	4%		Market Average	Concrete stair, 30% GGBS	2,634	-79%	-3.4%	Alternative to be discussed with HDR, concrete stair was initially rejected based on its weight and installation difficulties
	Handrail - structural steel profiles, 20% recycled content,	1,978	1%		Market Average	Timber handrails, 90% of volume	615	-69%	-0.5%	
	Railing - structural steel profiles, 20% recycled content,	1,275	0%		Market Average					

Potential Carbon Reductions

List of key building elements and carbon 'hot spots'

Table 7. Breakdown of carbon emissions of key building elements, potential material alternatives and resultant carbon reductions.

No.	Resource	Upfront Carbon A1-A5 (kgCO ₂ e)	Upfront Carbon A1-A5 (% of entire building)	Sequestration A1-A5 (kgCO ₂ e)	Data certainty	Alternative Resource	Alternative Upfront Carbon A1-A5 (kgCO ₂ e)	Potential change of Upfront Carbon of the Building Element A1-A5 (%)	Potential change of Upfront Carbon of the Entire Project A1-A5 (%)	Next stage
2.5 External Walls										
	Aluminium sheet, 30% recycled content, average European technology	8,255	3%		Market Average	Increasing recycled content of steel unlikely due to the low quantity of the material used on the project				Review the design of curtain wall with specialist contractor to minimise proportion of aluminium and steel
	Aluminium sheet, 30% recycled content, average European technology	8,255	3%		Market Average	Partial replacement with Equitone 8mm cement fibre boards, aluminium mullions to match board colour	7,806	-5%	-0.2%	Review the proportion of aluminium replacement, available colour and properties of cement board alternative
	Cross laminated timber	6,818	2%	-18,615	Market Average	Manufacturer specific alternatives available				For further reduction review manufacturer specific emissions and location of the factory.
	Rock wool insulation, unfaced	8,128	3%		Manufacturer specific	Manufacturer specific alternatives available				Review thickness of insulation against U-value, review density and EPDs of specific products
	Render	4,801	2%		Market Average	Manufacturer specific alternatives available				Review EPDs of specific products
	South - Insulated glazing, double pane	747	0%		Manufacturer specific	Manufacturer specific alternatives available				Review the design of windows with specialist contractor to minimise proportion of aluminium and steel. Review specification of glass with manufacturer
	North - Insulated glazing, triple pane - higher specification	1,735	1%		Manufacturer specific	Triple glazing assumed for carbon analysis to allow for higher glass specification such as e coating, gas filling, anti glare layer.				Review the design of windows with specialist contractor to minimise proportion of aluminium and steel. Review specification of glass with manufacturer
2.6 Windows & Ext. Doors										
	Aluminium frame window, double glazed, operable	8,987	3%		Manufacturer specific	Mixed aluminium exterior and timber interior frame	6,347	-29%	-0.9%	Value of carbon is highly dependant on specific product selected for the project
	Aluminium frame window, double glazed, operable	8,987	3%		Manufacturer specific	Manufacturer specific alternatives available				Review manufacturer specific EDP and detailed window design
2.7 Internal Walls & Partitions										
	Lining to concrete columns and blockwork	1,947	1%		Market Average	Manufacturer specific alternatives available. To be reviewed at Stage 4				Review performance and EPD of alternative products
	Lining to existing walls - Gypsum plasterboard	1,186	0%			Reduced to single board lining	593	-50%	-0.2%	Incorporate single board option into the design
	Internal Plasterboard Walls	19,574	7%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				Review performance and EPD of alternative products
	Blockwork and mortar	6,660	2%			Blockwork replaced with fire rated shaftwall	3,669	-45%	-1.0%	Alternatives to blockwork to be reviewed at next stage. The requirement for blockwork is driven by certified lift doors. If a fire rated lift door certified for fire rated shaft wall can be obtained, blockwork will be replaced with shaftwall.
	Aluminium framed glazed partition systems, single glazed,	2,318	1%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				Review manufacturer EDP for specific products
2.8 Internal Doors										
	Timber fire rated doors	2,025	1%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				Review manufacturer EDP for specific products. Carbon emissions highly dependant on specific manufacturer
	Glazed doors	1,179	0%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				Review manufacturer EDP for specific products. Carbon emissions highly dependant on specific manufacturer

Potential Carbon Reductions

List of key building elements and carbon ‘hot spots’

Table 7. Breakdown of carbon emissions of key building elements, potential material alternatives and resultant carbon reductions.

No.	Resource	Upfront Carbon A1-A5 (kgCO ₂ e)	Upfront Carbon A1-A5 (% of entire building)	Sequestration A1-A5 (kgCO ₂ e)	Data certainty	Alternative Resource	Alternative Upfront Carbon A1-A5 (kgCO ₂ e)	Potential change of Upfront Carbon of the Building Element A1-A5 (%)	Potential change of Upfront Carbon of the Entire Project A1-A5 (%)	Next stage
3.1	Wall Finishes									
	Paint to all walls	608	0%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				Review manufacturer EDP for specific products
3.2	Floor Finishes									
	RAF - tiles and pedestals	31,446	11%		Manufacturer specific	Floor tiles replaced with RMF Eco range tile	11,510	-63%	-6.8%	
	Finishes	3,850	1%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 3				Review manufacturer EDP for specific products
	GRP	2,236	1%		Market Average	Manufacturer specific alternatives available. To be reviewed at Stage 4				Review manufacturer EDP for specific products
3.3	Ceiling Finishes									
	Gypsum plasterboard ceilings with metal frame	466	0%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				
	Insulation and cement fibre board Lower Ground	4,626	2%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				
	Timber ceilings	5,636	2%		Manufacturer specific	Manufacturer specific alternatives available. To be reviewed at Stage 4				
	Gypsum plasterboard lining	1,087	0%		Manufacturer specific	Replace linning to slabs with paint	53	-95%	-0.4%	Review condition of floor slabs post soft strip
5	Services (MEP)									
	Electricity distribution system, cabling and central	13,593	5%		Market Average	Review qunatities of metals				Review with HDR Services
	LED overhead lighting system	13,293	5%		Manufacturer specific	Review light fittings poducts and obtain product specific carbon emissions				Review with HDR Services
	Air handling unit, with heat recovery through plate heat exchanger	6,217	2%		Market Average	Review qunatities of metals				Review with HDR Services
	Ventilation ducting, per m linear	6,313	2%		Market Average	Review qunatities of metals, consdier fabric ducting				Review with HDR Services
	Heat distribution system (water heat distribution) for educational or commercial buildings	2,569	1%		Market Average	Review qunatities of metals				Review with HDR Services

Upfront Carbon Analysis

Improvement against Baseline Carbon estimate

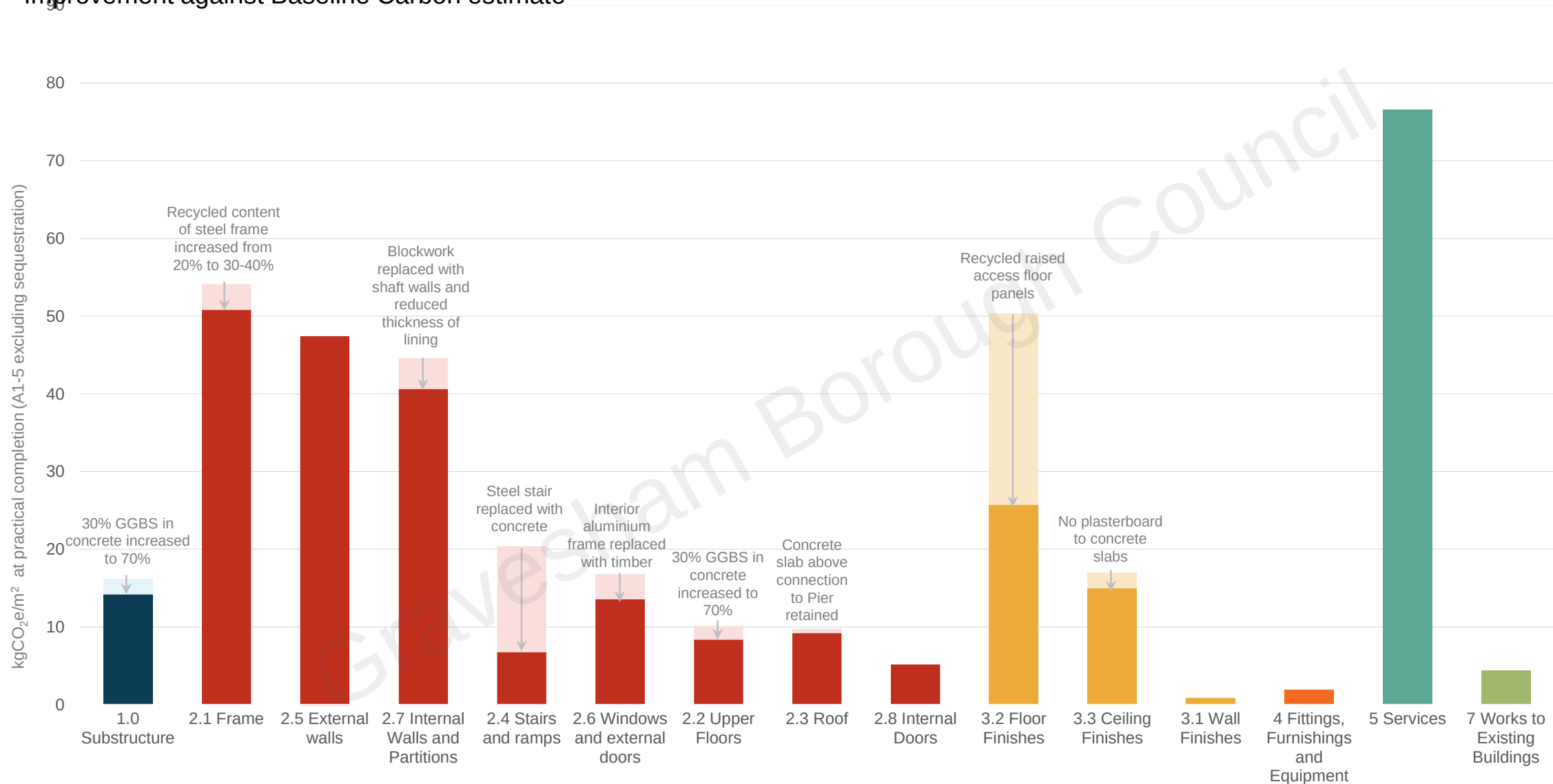


Figure 5. Overview of potential reductions in Upfront Carbon per m² of all building elements at Practical Completion (modules A1-A5)

Carbon Targets

Progress against project target

At the end of Stage 3, the baseline estimate is 375kgCO₂e/m² at practical completion (Upfront Carbon) and 706kgCO₂e/m² over the whole life of the building. Following the detailed analysis of individual building elements it is clear that there is a route to achieve the project Upfront Carbon target of 350kgCO₂e/m². We are also proposing that a stretch target is proposed of 321kgCO₂e/m² at practical completion, based on the assessment that if all potential reduction measures are implemented the current project is able to reach 321kgCO₂e/m². Achieving this stretch target would not be simple, with most carbon reduction options having some challenge in implementation.

The final Upfront Carbon of the project is influenced by all changes and decisions made in the following stages. It is therefore essential to update the carbon calculation at every stage of design to reflect specified products and increase accuracy of the study. Similarly, where key decisions are being made the carbon implications should be assessed alongside other factors.

The engagement of the contractor and their disclosure of as-built quantities and specifications is critical in ensuring successful completion of the project within the set carbon target. More information on key actions in the next RIBA stages are included at the end of the report.

Table 8. LETI Rating Matrix for Upfront Carbon, A1-A5 (exc. Sequestration)

Band	Office
A++	<100
A+	<225
A	<350
B	<475
C	<600
D	<775
E	<950
F	<1100
G	<1300

Project Stretch Target
321 kgCO₂e/m²

Project Baseline
375 kgCO₂e/m²

Project target
350 kgCO₂e/m²

Current best practice
600kgCO₂e/m²

Current industry average
950kgCO₂e/m²

Table 9. LETI Rating Matrix for Embodied Carbon, A1-A5, B1-B5, C1-C4 (inc. Sequestration)

Band	Office
A++	<150
A+	<345
A	<530
B	<750
C	<970
D	<1180
E	<1400
F	<1625
G	<1900

Project Stretch Target
601 kgCO₂e/m²

Project Baseline
706 kgCO₂e/m²

Current best practice
970kgCO₂e/m²

Current industry average
1400kgCO₂e/m²

Refurbished vs. New Build PCC

Gravesham Borough Council

Refurbished vs. New Build PCC

Estimate of Upfront Carbon if structure and external brick walls where not retained

The starting point for the project during RIBA stage 2 was to explore how to build less and achieve a lower carbon scheme. The initial assessment of the existing building suggested that the primary frame, the floors and walls could be retained and remodelled to meet contemporary performance standards. However working the existing building also poses challenges and limitations to the new design such as fixed structural grid, low floor to ceiling heights, additional surveys to confirm viability of retention.

The new build PCC building was one of the options discussed during early project stages. Although it was not developed further by the design team, this study takes into consideration carbon reductions achieved by retaining the existing structural frame, foundations, upper floor and external walls. Additionally some of the plant equipment serving PCC and adjacent Link Building is retained. Although it is not possible reliably to estimate upfront and embodied carbon of generator without its specification, the report highlights a significant carbon reduction associated with retention of generator, as back up plant is one of the most carbon intensive elements in any building.

The carbon estimate of the new build structure was based on the baseline design of structure around new core opening. The existing length of beams and columns, volume of foundations and area of floor slab were taken from the existing PCC Revit model. Properties of concrete and reinforcement within substructure were assume the same as the baseline estimate. The floor structure is assume to be composite metal deck with the same recycled content and % GGBS as the refurbished baseline. Beams are assumed to have the same properties and weight as the longest spanning beam around the core (254 UC 107, S355 with 20% recycled content). Type of columns was estimated as 203x203x73 UC using OneClick 3D Carbon Designer. The external walls on levels 0-3 in the new build option are assume to be blockwork and brick cavity wall with the same amount of insulation as the baseline scenario.

Table 10. Upfront carbon emissions of retained building elements and potential emissions in the new build scenario.

No.	Resource	Upfront Carbon A1-A5 (kgCO ₂ e)	Upfront Carbon A1-A5 (% of entire building)	Sequestration A1-A5 (kgCO ₂ e)	Data certainty	Alternative Resource	Alternative Upfront Carbon A1-A5 (kgCO ₂ e)	Potential change of Upfront Carbon of the Building Element A1-A5 (%)	Potential change of Upfront Carbon of the Entire Project A1-A5 (%)
Refurbishment vs New Build PCC									
	Omission of back up generator	0	0%		Manufacturer specific	Due to lack of generator specification, no carbon values were associated with generator. However power generators are one of the most carbon intensive plant elemenets and retention of generator results in significant carbon saving			
	Retianed substructure	0	0%		Market Average	Like for like replacement of piled founations	45,600	100%	15.5%
	Retained frame	0	0%		Market Average	Steel frame, design and specification based on alterations to existing frame	139,841	100%	47.6%
	Retained external walls, external render and insulation to retained walls	10,406	4%		Market Average	Blockwork and brick cavity wall	54,766	81%	15.1%

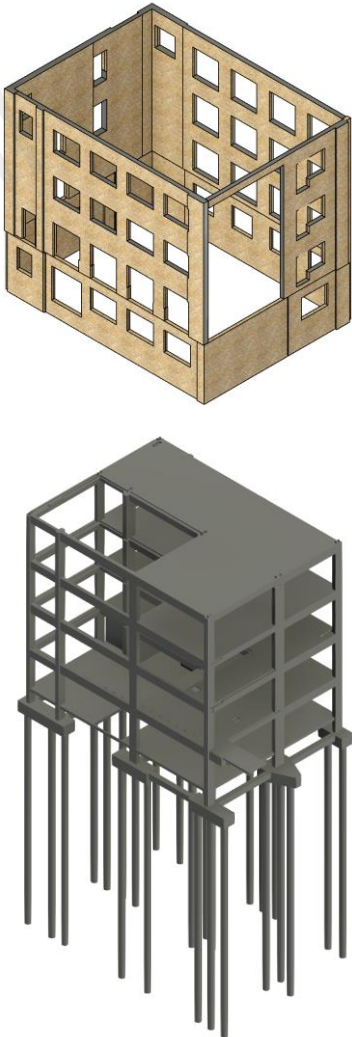


Image 1. Scope of retention: substructure, frame, floors and external wall.

Refurbished vs. New Build PCC

Estimate of Upfront Carbon if structure and external brick walls where not retained

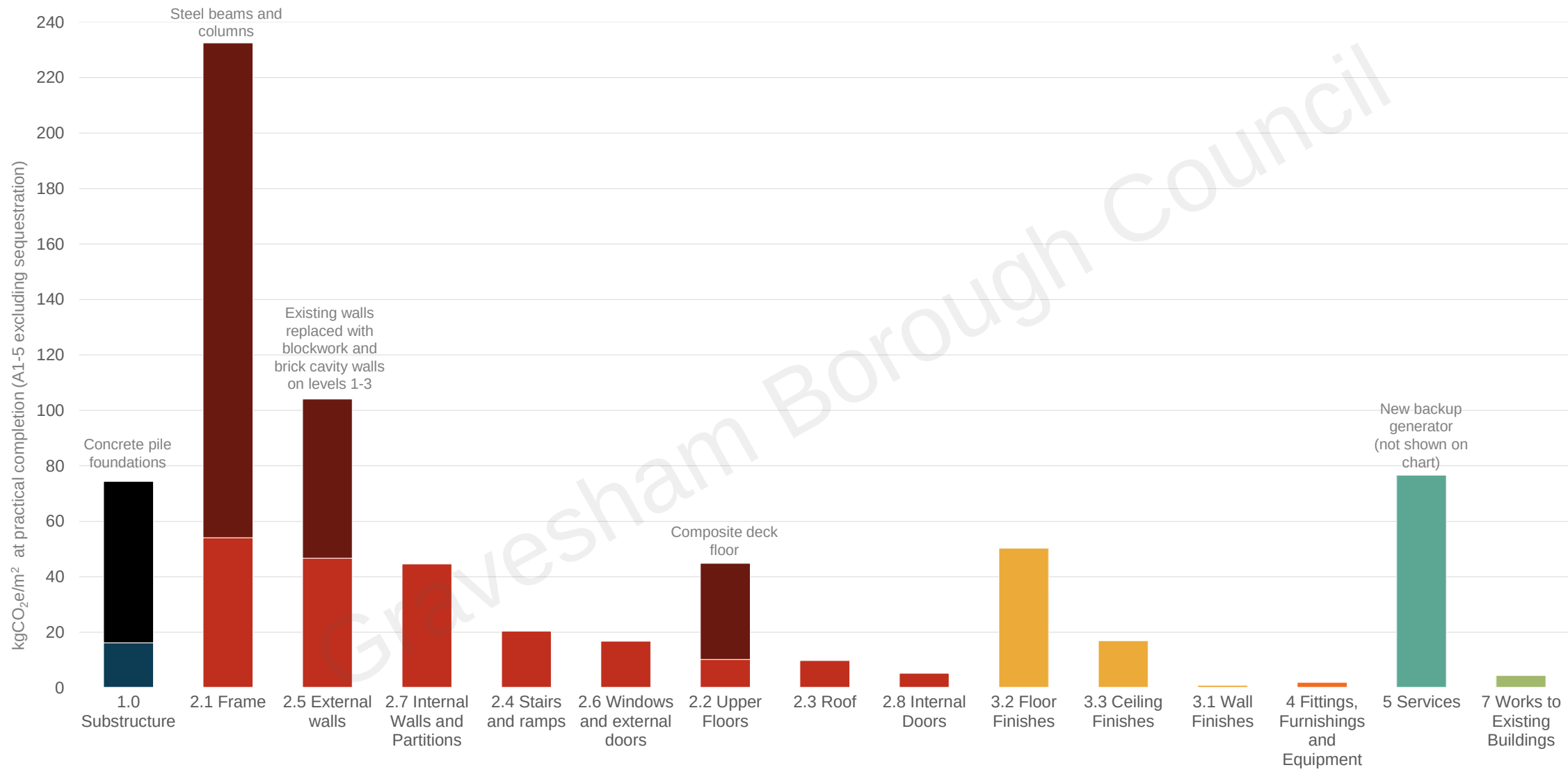


Figure 6. Overview of Upfront Carbon per m² of all building elements at Practical Completion (modules A1-A5). Increase of carbon due to demolition and redesign of structure and external walls indicated in darker tone against the baseline Upfront Carbon per m² values.

Refurbished vs. New Build PCC

Estimate of Upfront Carbon if structure and external brick walls where not retained

The Upfront Carbon of the new build version of PCC remains smaller than a typical office block by almost 250kgCO₂e/m². The proportional contributions towards the carbon footprint of various building elements matches an average office block in the UK. The amount of carbon associated with superstructure, especially frame and external walls has increased significantly in the new build design and it follows the trend in the industry. The contribution of superstructure and services towards the overall carbon footprint is smaller than average. The finishes are slightly higher than average, this is because average industry data is typically based on large, speculative, open-plan office blocks, with little divisions and finishes.

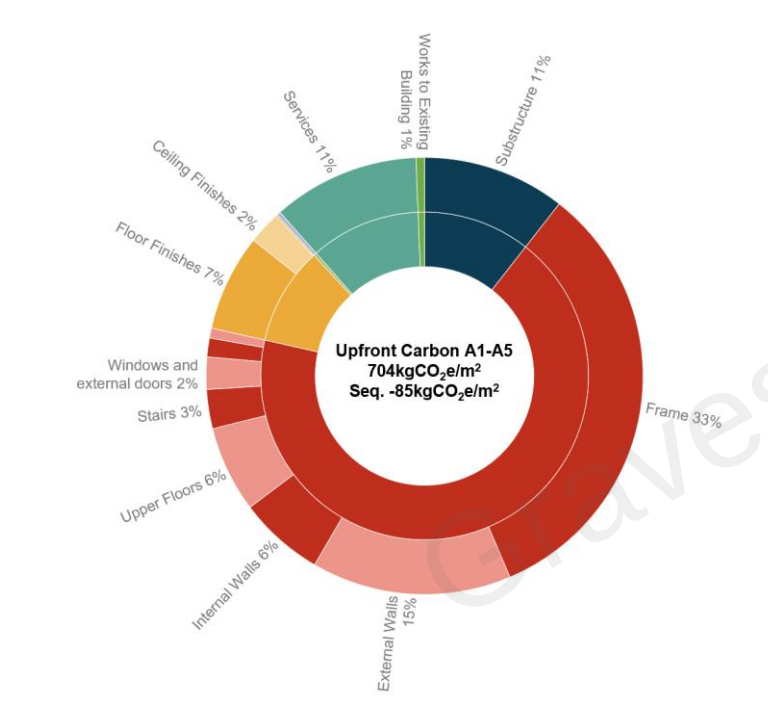


Figure 7. Breakdown of Carbon at Practical Completion (modules A1-A5) for a new build option of PCC, including new foundations, frame and external walls

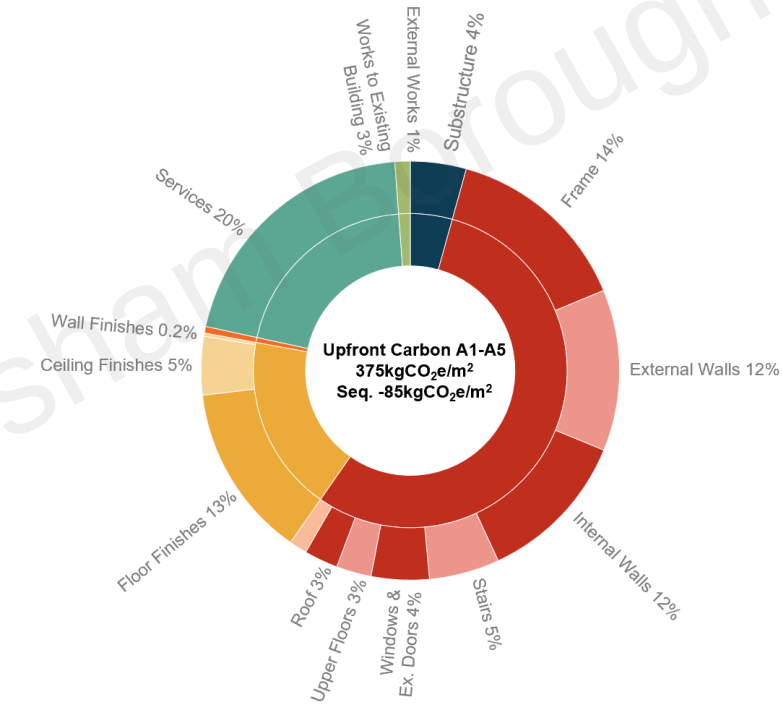


Figure 1. Overview of Upfront Carbon breakdown between all building elements at Practical Completion (modules A1-A5)

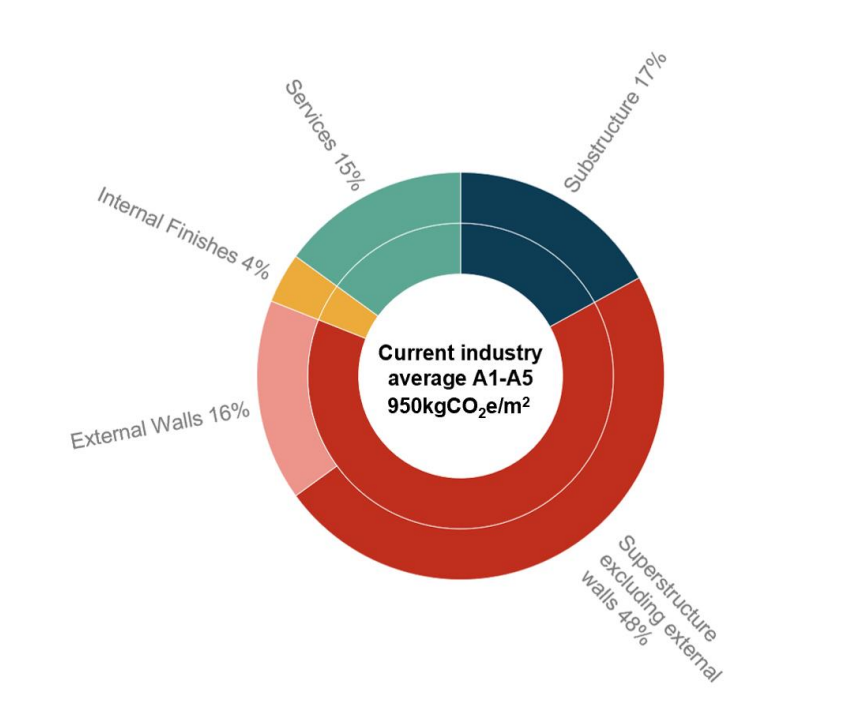


Figure 3. Typical breakdown between building elements at Practical Completion (modules A1-A5) for an average office building based on LETI Carbon Primer (p.26)

Carbon Targets

Progress against project target

Although the new build option could perform better than the industry average, it is double of the initial project target of 350kgCO₂e/m². Therefore, it would be challenging to outline sufficient reduction strategies for the new build option without a fundamental changes to the design. The study shows that retention of structure, external walls and foundation can have a significant impact in minimising carbon footprint and in some cases outweighs other carbon reduction strategies.

Table 10. LETI Rating Matrix for Upfront Carbon, A1-A5 (exc. Sequestration)

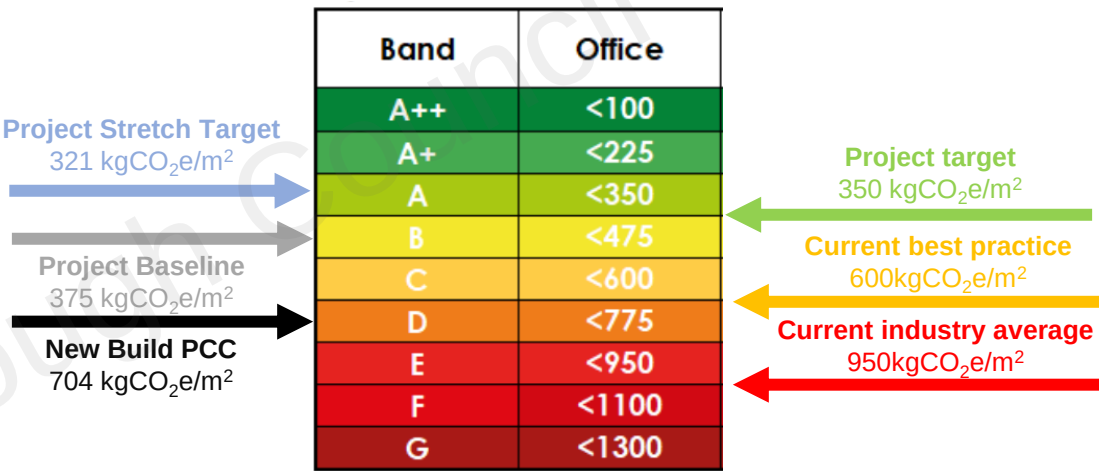
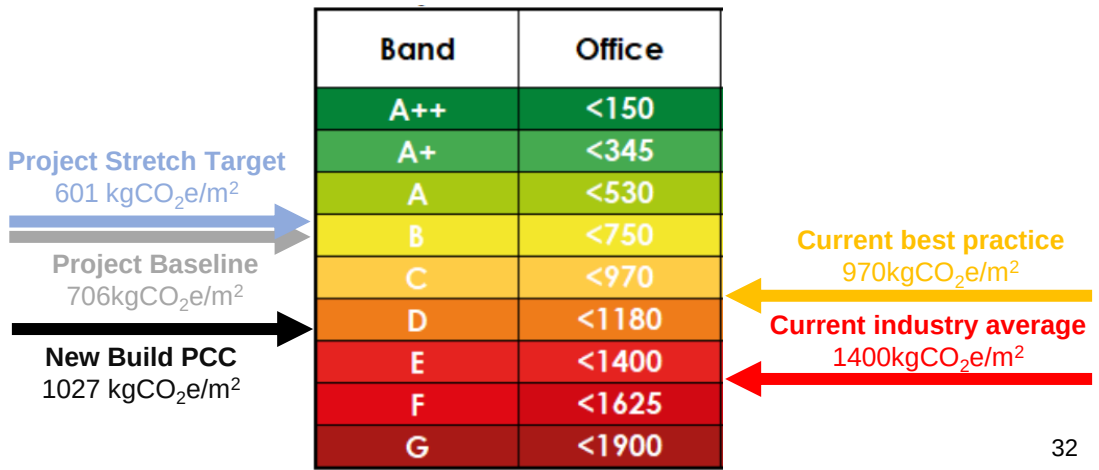


Table 11. LETI Rating Matrix for Embodied Carbon, A1-A5, B1-B5, C1-C4 (inc. Sequestration)



Next steps to achieve Net Zero Carbon

Gravesham Borough Council

Next Stages

Key actions

Stage 4 – Technical Design

- Incorporate alternative proposals where viable.
- Complete specification and detail design taking into consideration upfront carbon budget and overall carbon balance towards the target.
- Assess envelope specification taking into consideration both embodied carbon and energy modelling
- Based on the developed design update total upfront and embodied carbon and reassess both against LETI A rating target
- Publish current project totals publicly via Bennetts Associates website alongside energy targets

Procurement

- Include requirement to reach the upfront carbon target in the contractor's appointment
- Include requirement to collate and disclose as-build material quantities and specifications in the contractor's appointment

Stage 5 – Construction

- Work with contractor to identify and achieve greater efficiencies and carbon reductions
- Review any changes during construction against carbon targets
- Based on the as-build material quantities and specifications update total upfront and embodied carbon and reassess them against LETI A rating target

Stage 6 – Handover

- Review assumptions on replacement schedule and end of life scenarios
- Finalise total upfront and embodied carbon based on the as-build material quantities and specifications and use to update and reassess the project against the LETI A rating target
- To archive Net Zero Carbon emissions offset remaining emissions with a recognised offsetting framework and disclose the amount of offsets publicly (see next page)

Net Zero and Offsetting Schemes

Definitions and recommendations

Net Zero

To achieve Net Zero Carbon all carbon released throughout the construction and operation of the building need to be quantified and then offset using an independently audited and verified scheme. It is important to acknowledge that both renewables and offsets are a scarce resource. Hence buildings must use a “fair-share” of embodied carbon and operational energy, appropriate for its typologies. There are currently no government definition or planning of “fair-share” of embodied carbon and operational energy targets for the building industry. For the upfront carbon relating to the initial construction of a project, LETI rating scheme indicates the level of ambition of a project and helps define a “fair-share” of embodied carbon.

It is likely that there will be a fully recognised industry standard for net-zero carbon buildings before completion. Bennetts Associates is heavily involved in the creation of the standard and will therefore aim to future proof the project against any future certification requirements. It is expected that compliance with current LETI/UKGBC targets will be aligned.

Offsetting

Any remaining carbon should be offset using a recognised offsetting and/or removal framework. Offsets should either be procured directly or via recognised existing frameworks. Both of these routes should seek to demonstrate additionality, avoid double-counting and provide a clear process for verification of carbon savings. Procurement of offsets and/or removals for net zero carbon construction should reflect the carbon impacts determined from as-built data after the practical completion.

For the offsetting to be meaningful it is very important that it is additional, permanent (lasting minimum 100 years) and measurable. It is recommended by the UKGBC that a carbon price of approximately £75/tonne is set which would be used to fund purchasing of offsets with the remaining used for reducing emissions in non-verified ways such as PLA fleet upgrades.

Public disclosure

The total emissions of the building should be publicly disclosed alongside any abnormal assumptions following current industry best practice. The amount of offsets used should also be publicly disclosed. Carbon offsets represent the final step to achieving a net zero carbon building, as industry feedback has raised concerns regarding the reliability of carbon abatement through offsets.

For more information on Net Zero and offsetting operational energy please refer to UK Green Building Council publication ‘Net Zero Carbon Buildings: A Framework Definition’ and its ‘Renewables and Offsets Guidance’

Gravesham Borough Council