55 BISHOPSGATE

October 2022

Whole-Life Carbon Assessment

55 BG Unit Trust

55 Bishopsgate

Stage 2 Life Cycle Assessment (LCA)

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Contents

1 Executive Summary

1.1 Project overview

This report presents the outcome of the Stage 2 carbon assessment performed for 55 Bishopsgate, a commercial tall building development in the City of London, which if granted planning permission would be expected to be completed in 2030. The assessment included an analysis of the project embodied carbon to practical completion (EC-PC) over the building lifecycle (EC-LC), for which a reference study period of 60 years was assumed. The results therefore represent a point-in-time assessment based on the design information provided by Robert Bird Group (structural and civils design) and Arup Facades (building envelope design) and the cost plan tracker shared by Alinea (quantity surveyors). Where materials could not be quantified due to constraints of the design stage, the embodied carbon estimate was based on benchmarks, which is deemed suitable considering the early stage of assessment.

This report should be read in conjunction with the Circular Economy Statement, also submitted as part of this application, which includes a pre-redevelopment audit.

1.2 Results

The Stage 2 submitted embodied carbon impact can be summarised as follows:

- EC-PC (A1-A5): approximately **863 $kgCO_2e/m^2$ GIA**
- EC-LC (A-C excl. B6 and B7): approximately **1,385 $kgCO_2e/m^2$ GIA**

This embodied carbon performance falls within the GLA benchmark range for embodied carbon intensity, however sits outside of the GLA ‘aspirational’ range. It falls within Band E of the LETI carbon rating scheme for both A1-A5 and A-C.

The superstructural frame is the largest contributor to the total embodied carbon. The carbon impact of the façade and building services is also significant, each equal to about 10-15% of the frame’s carbon intensity to practical completion (EC-PC).

The project has undergone an extensive Stage 2 development process, during which time the baseline has been refined several times, and a number of carbon reduction opportunities have been incorporated into the design. The most impactful of these is a switch to higher strength steel in the primary mega-frame, which has resulted in a reduction in steel tonnage, and a client commitment to the procurement of low carbon steel for the primary mega-frame and all rolled sections.

Several further carbon reduction opportunities have been assessed to identify where further savings can be made. A total of 3.7% A1-A5 (2.4% A-C) savings have been identified, the majority of these (2.3% A1-A5) are derived from further procurement of low carbon steel.

	Embodied Carbon at Practical Completion (A1-A5)		**Embodied Carbon at over Life Cycle (A-C excl. B6-7)**	
	tCO_{2e}	**$kgCO_{2e}/m^2$ GIA**	**tCO_{2e}**	**$kgCO_{2e}/m^2$ GIA**
Stage 2 Baseline (P02)	130,000	**1,017**	221,000	**1,727**
Stage 2 Submitted (P05)	109,078	**863**	175,103	**1,385**
Potential	105,866	**837**	166,954	**1,320**
Potential additional savings (%)		**3.7%**		**2.4%**

1.3 Key recommendations and next steps

- Given that the carbon reductions already identified and captured in the design are concerned with the procurement of steel, early engagement with steel manufacturers and specialist contractors must be prioritised, to ensure that the ambitious carbon factors targeted remain viable, and that these savings can be realised.
- Following the initial optioneering study detailed below, the carbon reduction options tested demonstrate that further opportunities for carbon saving are viable. Examples include the floor slab design and the substructure design. Further analysis and viability assessment must be carried out at the next design stage to establish the magnitude of potential reductions.
- The whole life carbon assessment is an ongoing process throughout the design programme, and it is expected that further carbon reduction opportunities will be identified at later stages.

2 Introduction

2.1 Background

The proposal for 55 Bishopsgate, herein referred to as the proposed development, involves the development of a new-build commercial tall building in the City of London. It consists of a main tower building, with 64 storeys above ground and 3 levels of basement, and an adjacent satellite tower.

The proposed development will have a Gross Internal Area (GIA) of 126,476 m^2. The office Net Internal Area (NIA) will be 77,162m^2.

2.2 Aim and objectives

The aim of this study is to assess the embodied carbon associated with the proposed development and provide recommendations for reducing this.

The following objectives help to achieve this aim:

- Inform the design team of the embodied carbon associated with the Stage 2 design at practical completion (modules A1-A5) and over its life cycle (60 years, modules A-C);
- Identify the key building elements with the highest embodied carbon ($kgCO_2e$); and
- Investigate a range of major interventions to determine options for carbon emission reduction, in line with Stanhope's commitment to achieving net zero carbon at practical completion in 2030. This exercise also satisfies the requirements of BREEAM NC2018 Mat01.

2.3 Planning Policy and Guidance

This WLCA has been prepared in response to the planning requirements and guidelines outlined in the following documents:

- The London Plan 2021 – The Spatial Development Strategy for Greater London (2021) (Greater London Authority (GLA)
- London Plan Guidance – Whole Life-Cycle Carbon Assessments (March 2022) (Greater London Authority)

The London Plan 2021 – The Spatial Development Strategy for Greater London (2021)

The London Plan Chapter 9: Sustainable Infrastructure, sets out the new targets for sustainable design. It includes the following strategic policies that are relevant for this development's sustainable building design:

Policy SI2 Minimising greenhouse gas emissions:

> ***F*** *Development proposals referable to the Mayor should calculate whole life-cycle carbon emissions through a nationally recognised Whole Life-Cycle Carbon Assessment and demonstrate actions taken to reduce life-cycle carbon emissions.*

> ***9.2.11 Operational carbon emissions*** *will make up a declining proportion of a development's whole life-cycle carbon emissions as operational carbon targets become more stringent. To fully capture a development's carbon impact, a whole life-cycle approach is needed to capture its* ***unregulated emissions*** *(i.e. those associated with cooking and small appliances), its* ***embodied emissions*** *(i.e. those associated with raw material extraction, manufacture and transport of building materials and construction) and emissions associated with maintenance, repair and replacement as well as dismantling, demolition and eventual material disposal).* ***Whole life-cycle carbon emission assessments are therefore required for development proposals referable to the Mayor.*** *Major non-referable development should calculate unregulated emissions and are encouraged to undertake whole life-cycle carbon assessments. The approach to whole life-cycle carbon emissions assessments, including when they should take place, what they should contain and how information should be reported, will be set out in guidance.*

London Plan Guidance – Whole Life-Cycle Carbon Assessments (March 2022)

This guidance explains how to prepare a Whole Life-Cycle Carbon (WLC) assessment in line with Policy SI 2 F of the London Plan 2021 using the WLC assessment template. Policy SI 2 F applies to planning applications which are referred to the Mayor.

This guidance explains how to calculate WLC emissions and the information that needs to be submitted to comply with the policy. It also includes information on design principles and WLC benchmarks to aid planning applicants in designing buildings that have low operational carbon and low embodied carbon.

City of London Planning Advice Note – Whole Lifecycle Carbon Optioneering (July 2022)

The requirements of the draft PAN are addressed in the pre-redevelopment audit, appended to the Circular Economy Statement.

2.4 Project Whole Life Carbon (WLC) Principles

The London Plan Guidance for 'Whole Life-Cycle Carbon Assessments' sets out guidance for project teams when undertaking analysis. This includes a set of principles which should be used to guide teams towards appropriate solutions.

The table below summarises the proposed development's response to these principles. This response is aligned with the circular economy commitments detailed in the Circular Economy Statement and summarised in the Sustainability Development and Climate Change Report submitted as part of this application, and which should be read in conjunction with this report.

Principle	Project implementation
Reuse and retrofit of existing built structures	The team assessed the feasibility of reuse, retrofit or expansion the existing building at feasibility stage, or RIBA Stage 1. Further details on this analysis can be found in the Pre-redevelopment Audit, submitted as part of the Circular Economy Statement. The project ambition is to ensure that the new development will support urban densification by providing significant additional floor area, and that it will remain flexible enough and fit for purpose for a long period of time. These project aspirations meant that refurbishment was not considered to be feasible. The team therefore focused on **minimising the carbon impact of the new development**. To mitigate the impact, the following circular commitments were adopted: • Maximise the volume of existing materials that remain in use • As part of the P**re-redevelopment Audit,** identified quantities, potential uses, markets and targets for anticipated waste streams, in order to maximise the value of the existing materials and components. • **Minimum Waste development**: No construction waste will go to landfill
Use repurposed or recycled materials	In order to achieve the proposed development's embodied carbon ambitions, the Design Team focused on **low carbon specifications as a key priority** including **high rates of recycled content** and the use of reclaimed materials.
Material selection	While not included in the baseline figures, the project team intends utilise reused steel within the floor slab design. As the design develops, further opportunities to use reclaimed materials, either from the existing building or others, will be sought.
Minimise operational energy use	The proposed development has the aspiration to align the Energy strategy and performance to NABERS UK minimum 5 Stars, aspirational 5.5 stars.
Minimise the carbon emissions associated with operational water use	All available credits in the BREEAM Water section, including measures to reduce water consumption, monitor consumption, detect leaks and procure water-efficient equipment. In addition to water-efficient fittings, the Proposed Development includes 100% greywater recycling and is also considering rainwater harvesting during the design development.
Disassembly and reuse	Critical components are designed to be 'loose fit', to facilitate easy repair and refurbishment, including: Façade (unitised components), Partitions, Finishes and Building Services.
Building shape and form	The proposed development is designed with a compact, efficient shape to minimise both operational and carbon emissions.
Regenerative design	Vegetation will be maximised through the use of green walls on the façade, and planting on the rooftop conservatory.
Designing for durability and flexibility	Critical building components are designed for **longer service life** than average construction practice. **Horizontal flexibility** is key in the design of the proposed development, which provides column-free floor plates allowing multiple layouts for various tenant types / use sectors
Optimisation between operational and embodied carbon	The **façade design** has been optimised for whole life carbon, balancing the impacts of embodied and operational emissions: A **flexible system** to optimise glazed areas coordinates provision of daylight, glare control and the reduction of solar gains depending on orientation, height and external conditions. This system avoids the inclusion of additional shading material.
Building life expectancy	The Whole-Life Carbon Assessment has been calculated for the typical lifespan of **60 years**. However, the proposed development's substructure and superstructure will be designed for **100 years** to ensure that under the right conditions the building can have longer lifespans. To support the building to remain fit for purpose for as long as possible, **flexibility and adaptability** is critical: Generous floor to ceiling height, column-free floor plates, due to site footprint and core, and demountability of the façade and partitions address this outcome.
Local sourcing	**Local selection and sourcing** of materials will be favoured provided that these can be achieved without compromising environmental impact. E.g. if the environmental/carbon impact of a locally produced or sourced material is higher than sourcing the same component from elsewhere, the Whole-Life balance (including transport) will be used to decide procurement. Landsec has a commitment to procuring all materials from the UK and EU only, unless specifically agreed otherwise.
Minimising waste	The proposed development commits to diverting 100% of non-hazardous waste from landfill and 95% of total waste from landfill
Efficient construction	The proposed development has defined efficient **Modern Modes of Construction**, prefabrication and loose fits in key building components: Superstructure, Façade, Partitions, Finishes, Building Services. This approach will better build quality, reduce construction-phase waste and reduce the need for repairs in the post-completion and defects period.
Lightweight construction	The proposed development incorporates **lean design** as a priority to reduce the weight of the building: • The steel mega-frame structure reduces the weight of the structure relative to a conventional outriggers scheme • Higher strength steel is being targeted to reduce the weight of the structure further
Circular economy	Circular Economy aspirations are defined in the Circular Economy Statement submitted as part of this application.

2.5 RIBA Stage 2 design strategy

The proposed development consists of a steel-concrete composite frame with concrete core and lift shafts, a steel megaframe on the perimeter and composite floor slabs. 64 storeys above ground are proposed to sit atop a 5-storey concrete piled basement. External areas are to consist of pedestrianised public realm.

Substructure: Secant pile walls and pile raft foundation. A retaining wall will be installed to locally extend the basement down to B4.

Frame & upper floors: Basement levels and ground floor consist of reinforced concrete floorplates and concrete cores and columns. Upper floors consist of composite metal decking with a perimeter steel megaframe and concrete cores. The steel megaframe has been designed using Michell Truss theory and biomimicry to achieve material efficiencies and a flexible internal space. The megaframe is within the building envelope and therefore has been designed for internal exposure conditions. The main tower has an approx. 40mx40m floorplate while the satellite tower has an approx. 20mx20m floorplate.

External walls: The closed-cavity curtain wall façade comprises vertical and inclined sections to achieve the visual effect of the building tapering with height. Some panels will include an external aluminium feature to replicate and highlight the internal perimetral structural megaframe. The ground floor area includes a stick system facade. The LCA assessors have been advised that the proposed façade system will have a design life of 60 years, except for the glass which will have a design life of 30 years.

Roof: Reinforced concrete slab with insulation and waterproofing. The main tower includes a roof garden contained within a glass enclosure.

MEP services: Reflecting the early stage of design development, there is insufficient data to quantify MEP services for an embodied carbon assessment, therefore Arup and OneClick benchmarks normalised by area have been used. The exceptions to this are lifts, for which more detailed quantification has been provided, enabling these to be explicitly modelled in OneClick.

External works: External works will mainly consist of hard landscaping, assumed to be Yorkstone paving at the current design stage, as per City of London design standards. Public realm at ground floor will also include a garden and seating areas. To achieve an Urban Greening factor of 0.4, a green wall is featured in between the satellite and main towers.

2.6 Declaration of qualifications

The analysis was undertaken by an Arup assessor who has more than three years' experience in building engineering including undertaking sustainability assessments, life cycle assessment options appraisals and whole life carbon assessments. The work has been reviewed by an Arup Senior Sustainability Consultant and chartered architect with 10 years' experience in the built environment sector, and 4 years' experience in conducting LCAs for the built environment.

2.7 Third-party verification

Cundall have undertaken a third-party verification process on this assessment, the results of which are appended to this report.

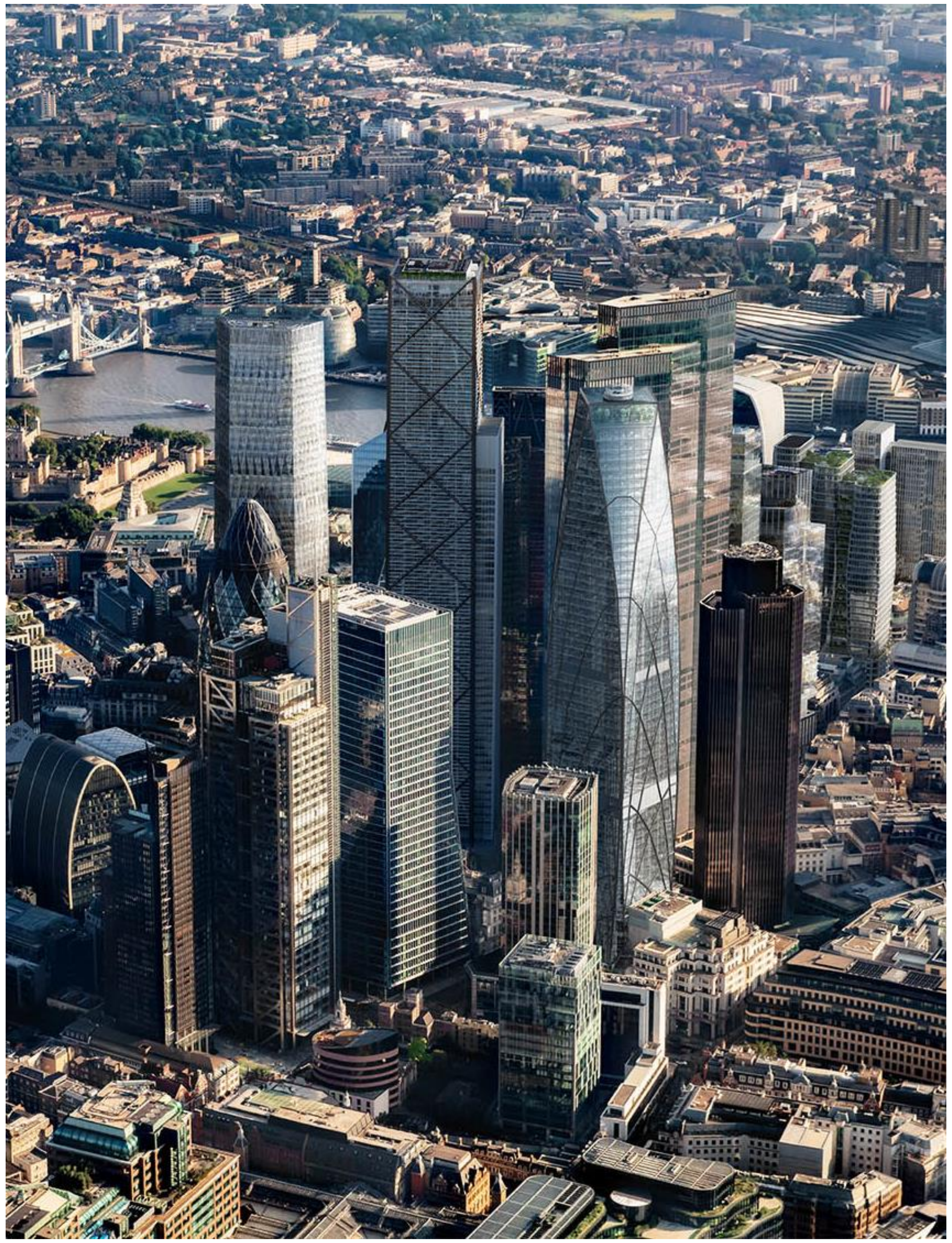


Figure 1: Architectural render of 55 Bishopsgate in London skyline (courtesy of AFK).

2.8 Development of Stage 2 assessment

This LCA has been conducted to incorporate Stage 2 design changes to structural massing, material quantities and specifications as advised by the design team and cost consultants. The assessment has undergone several iterations, each time refining the assumptions following more detailed input from the design team, and incorporating carbon reductions.

2.8.1 Stage 1+ to Stage 2 P01

The key changes include the following (impact in **bold**):

- Addition of 250mm thick blinding layer at lowest level. This is significant as it is assumed no cement replacement is specified for the concrete mix. **Increase in A-C.**
- Greater clarity on number of lifts. **Increase in A-C, particularly B modules.**
- Concrete grades as per ‘4352-DN-S-001 Concrete Material rates’ by RBG. These have generally increased for walls and columns but decreased for floors.
- Change from lightweight aggregate concrete in composite floors to normal-weight concrete. **Decrease in A1-A3.**
- Updated structural quantities for basement and foundations. **Decrease in A-C.**
- Steel tonnages and proportion of fabricated vs rolled standard sections for steel superstructure elements as per latest cost tracker (1st February 2022) and Alinea correspondence (email dated 4th February 2022). Allowances (for connections and secondary steelwork) understood to be included within cost tracker material quantities. Therefore, revised design contingencies (10.25% vs previous 21%) are now applied to steel tonnages *including* allowances.
- A5 site operation impacts split per building element. The previous assessment combined these impacts together, skewing the results when comparing the building element impacts to benchmarks.

The above presents a summary of the refinement of the baseline embodied carbon impacts of the proposed development. The overall change can be seen to be a reduction of approximately 9% in the embodied carbon to practical completion (modules A1 – A5), but only a marginal reduction in the whole life (EC-LC) embodied carbon (modules A – C). This is mainly attributable to the more detailed number of lifts within the cost plan being reflected in the model and resulting in a large increase in the embodied carbon impact associated with building services.

Owing to the whole life carbon ambitions for the project and the relatively high level of detail already developed in the structural design for such an early stage, the proposed development Stage 2 LCA has already accounted for proposed material specifications. The material assumptions used for the main construction materials within the OneClick model are presented in Table 1.

The levels of cement replacement assumed for most concrete elements reflect industry best practice at the time of writing this report. The exceptions to this are the concrete cores, which have an estimated 20% cement replacement, owing to the slipform construction method proposed. Slipform construction relies on early age strength gain, which is hindered by high levels of cement replacement, and will require concrete to be pumped to heights above 100m for the proposed development, which will favour PFA over GGBS as cement replacement. Considering the lower availability of PFA and the lower cement replacement allowance with PFA for a given concrete strength compared with GGBS, a 20% cement replacement allowance has been assumed for the cores at this stage. RBG will discuss and review this assumption with a concrete contractor as the design progresses.

As the carbon impact of concrete elements depends on the cementitious content assumed, this assumption for different concrete mixes modelled within OneClick is presented in Table 2. It is important to note that if the concrete mix design at later stages were to specify a higher cementitious content, the carbon impact would increase, all other things being equal. Therefore, future assessments should verify that the assumptions presented in Table 2 are still applicable.

2.8.2 Stage 2 P01 to Stage 2 P02

The key changes include the following (impact in **bold**):

- Ready-mix concrete carbon factors have been updated (see Table 1) based on updated Environmental Product Declaration (EPD) data. **Decrease in A-C.**
- Steel sheet carbon factors have been updated based on UK average consumption data. **Decrease in A-C**.

2.8.3 Stage 2 P02 to Stage 2 P03

The key changes include the following (impact in **bold**):

- High strength, S460 steel has been adopted for the mega-frame and satellite columns, resulting in a 26% and 9% reduction in steel tonnage respectively. **Decrease in A1-A3**.
- Proportion of fabricated vs rolled standard sections for steel superstructure elements updated to align with latest design development. For example mega-frame changes from 50% - 50% split to 84% rolled sections and 16% fabricated sections. **Decrease in A1-A3**.
- ArcelorMittal HISTAR steel (0.52 kgCO2e/kg A1-A3) has been adopted for the rolled steel sections. **Decrease in A1-A3.**
- New method for calculating B2 and B3 emissions based on available RICS guidance. **Decrease in A-C.**

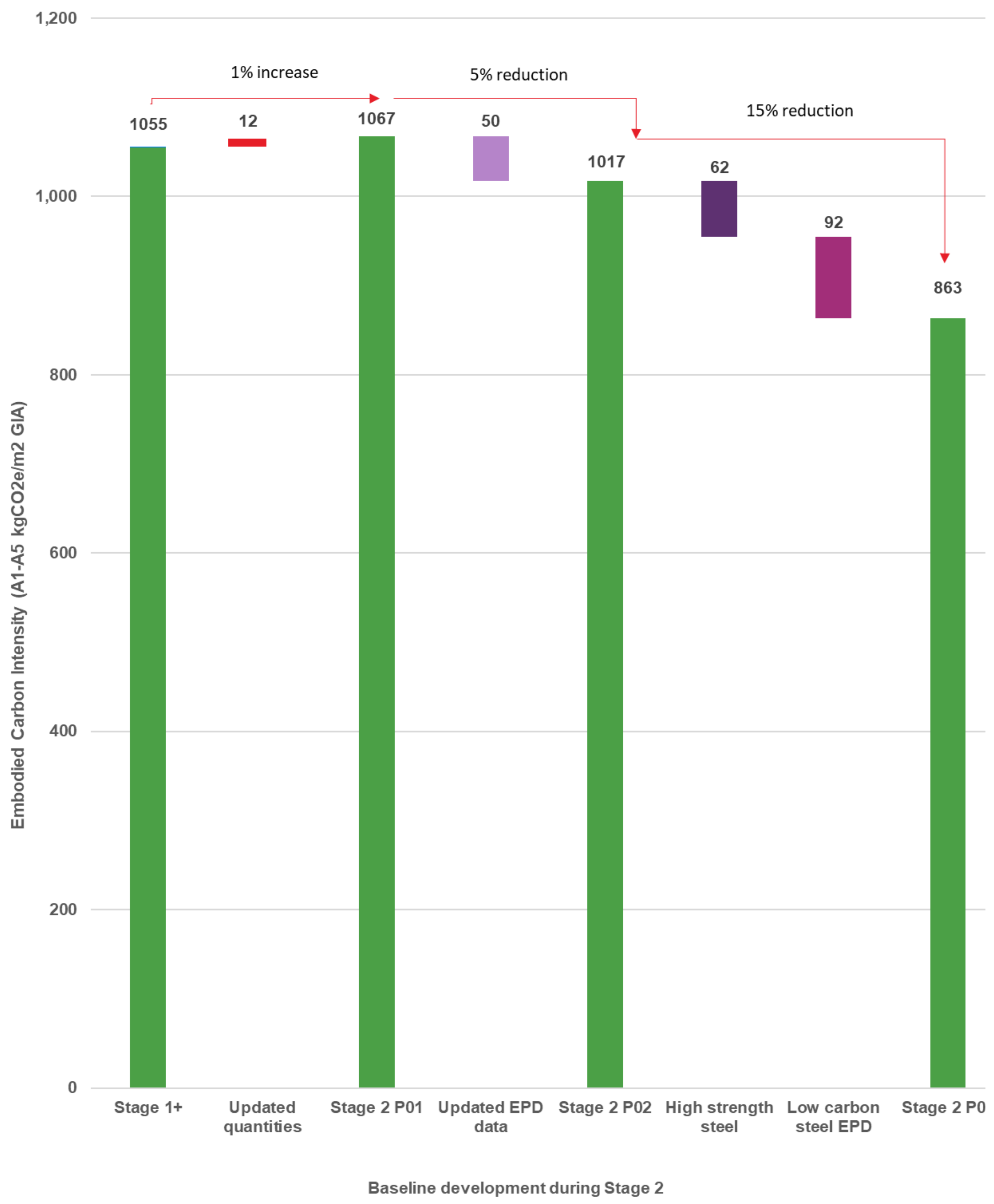


Figure 2: Development of assessment in A1-A5 impact during Stage 2

Table 1 Baseline construction materials assumptions

Material	Details	Specification	A1-A3 Carbon Factor ($kgCO_2e/kg$)
Concrete	Piling	Varies (C32/40-C40/50) 70% cement replacement	0.07
	Substructure	Varies (C32/40-C50/60) 70% cement replacement[a]	0.07 – 0.14
	Superstructure – basement slabs + columns	C40/50 50% cement replacement	0.10
	Superstructure – composite and roof slabs	C30/37 50% cement replacement	0.08
	Superstructure – core walls	Varies (C32/40-C50/60) 20% cement replacement[a]	0.11 – 0.15
	Generic concrete (e.g., blinding)	C16/20 0% cement replacement	0.11
Steel	Structural steel sections – fabricated	20% Recycled Content	2.45
	Structural steel sections – standard	ArcelorMittal HISTAR (100% Recycled Content)	0.52
	Reinforcement bars	97% Recycled Content	0.50
Timber	Formwork	18mm Plywood	0.53
Aluminium	Façade	Aluminium 31% scrap content	6.83

Notes:
[a] The structural team (RBG) have advised that a minimum of 50% and 70% cement replacement via GGBS will be specified for concrete in the superstructure floors and substructure, respectively. Embodied carbon data is available within OneClick for these levels of cement replacement for grades up to C40/50. For C50/60, the database provides a maximum cement replacement with GGBS of 30%, therefore this is used for superstructure entries. This is a conservative assumption, as increasing the cement replacement will have a greater embodied carbon reduction for higher grades, as cementitious content increases with concrete grade.

Table 2: Cementitious content assumption built into each of the OneClick resources used for concrete.

Cementitious Content Assumption (kg/m^3)		GGBS proportion modelled			
		20%	30%	50%	70%
Concrete grade	C30/37	-	-	300	-
	C32/40	320	-	-	340
	C40/50	400	-	400	400
	C50/60	430	430	-	-

3 Results

3.1 Whole Life Carbon (embodied and operational)

The whole life carbon calculation considers both embodied and operational carbon impacts over a 60-year reference study period. The embodied carbon assessment follows the methodology and model basis outlined in Appendix A and B, and the results are presented in more detail in Section 3.2.

The operation of the site is to be all electric. The regulated and unregulated energy demand has been provided by MEP engineers (Hilson Moran) based on their Design for Performance (DfP) Stage 2 operational energy modelling to CIBSE TM54. The modelling results for the 'Central Case (Normal Management)' scenario for the whole building have been used in the LCA (see Figure 3 and Table 3). The model includes the energy consumption related to heating, cooling, hot water, lighting, auxiliary and small power, while catering and vertical transportation are to be included within a future iteration. This has been converted to GIA for the purpose of this assessment.

Table 3: Operational energy values used in LCA.

Regulated: Heating, Cooling, Hot Water, Lighting, Auxiliary	4,008,920 kWhe / year
Unregulated: Small Power	5,412,050 kWhe / year

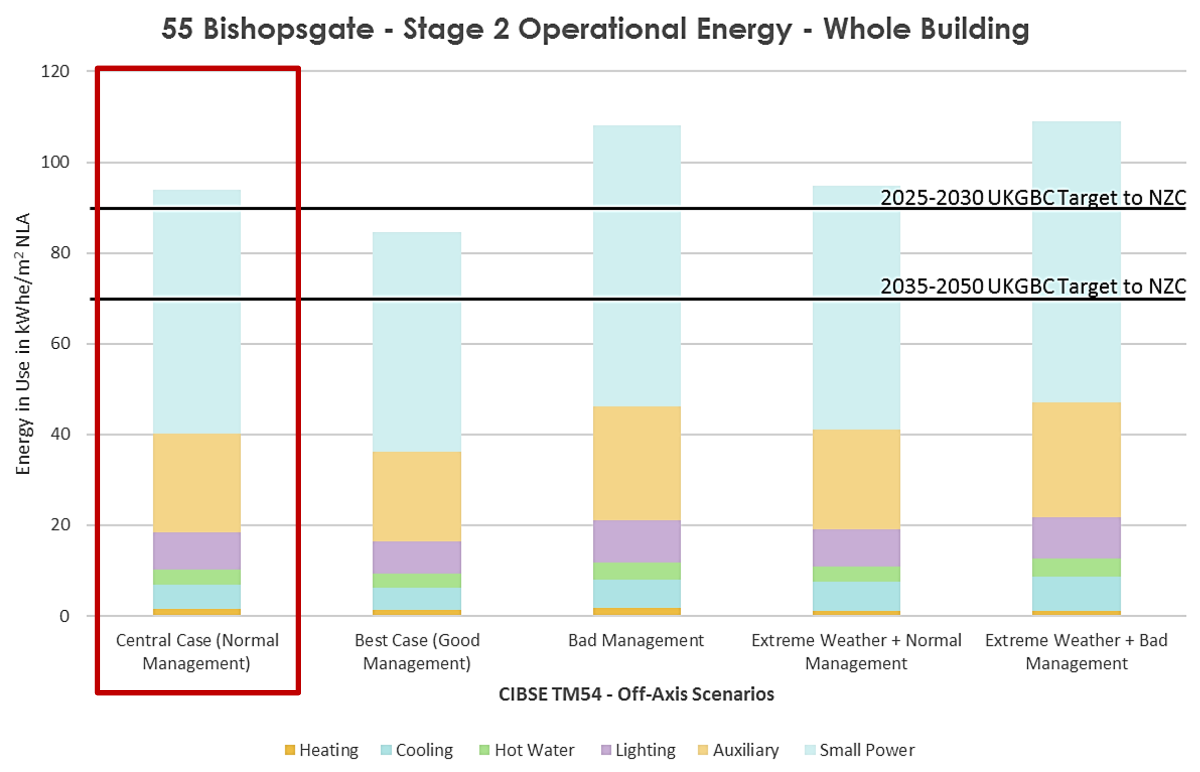


Figure 3: Operational energy model results by Hilson Moran.

The operational water use has been estimated at 30,000m^3/year, assuming a 10m^2 above ground NIA/person occupancy, as advised by the public health engineer, a use of 240days/year and a water consumption of 15.81L/person/day.

The total whole life carbon figure for the baseline model **without grid decarbonisation** is approximately **204,000 tCO_2e** (equivalent to 1,595 kgCO_2e/m^2). When grid decarbonisation is disregarded, the whole life carbon is split approximately in a 1:2 ratio between operational and embodied carbon as can be seen in Figure 4. The grid carbon factor for electricity from the Government's Standard Assessment Procedure for Energy Rating of Dwellings, Version 10.1 (SAP 10.1) was used for the calculation of the carbon impact of operational carbon and IEA2018 was used for the calculation of embodied carbon, both without grid decarbonisation.

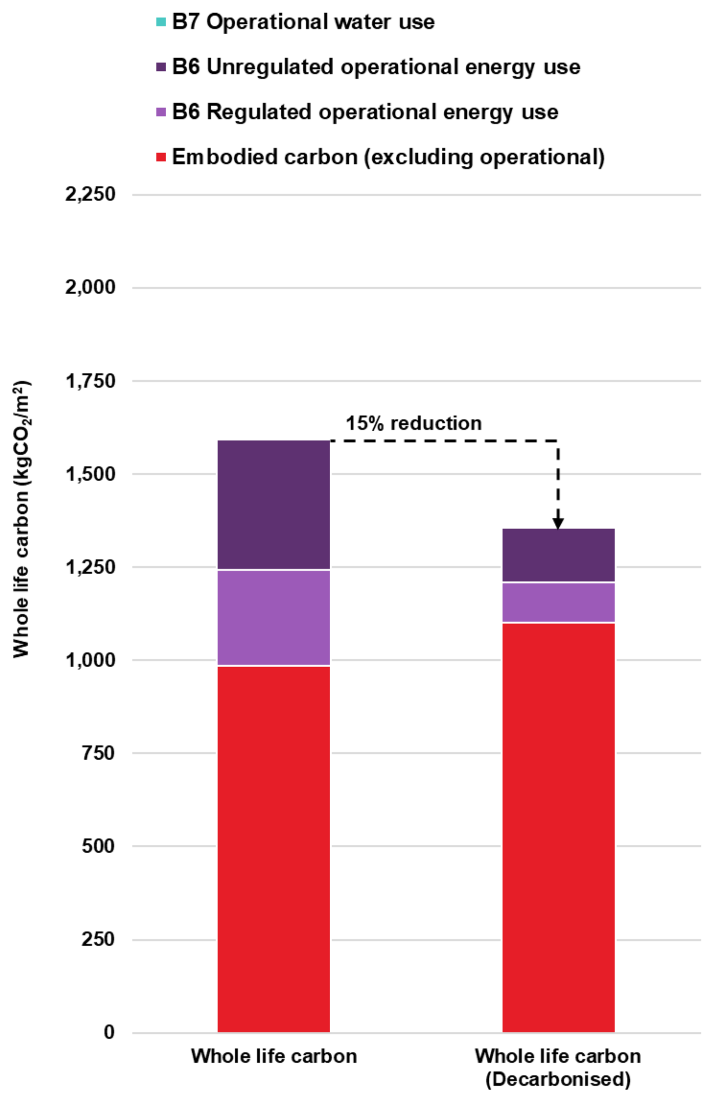


Figure 4: Whole life carbon emissions of the Stage 2 Baseline with and without grid decarbonisation over life cycle (A-C). Benchmark allowances for internal partitions, finishes, FF&E and external works, and contingencies are not included.

Accounting for grid decarbonisation means B and C stages, covering the in-use and end-of-life embodied carbon associated with materials and the operational carbon from the energy use during the operational life of the building, were calculated using future carbon factors energy. The WLC calculation with grid decarbonisation was based on:

- Decarbonisation coefficients obtained from the FES 2021 'Steady Progression' scenario with 2022 as the base year for the embodied carbon for materials maintenance, repair, replacement and end-of-life (B2-B5 and C modules). This calculation was performed within the OneClick LCA model with the fixed inbuilt assumptions outlined.
- Decarbonisation coefficients obtained from the FES 2021 'Steady Progression' scenario with 2030 as the base year for the operational carbon calculation.

The carbon conversion factor for both calculations was taken as the 2022 value from SAP 10.1.

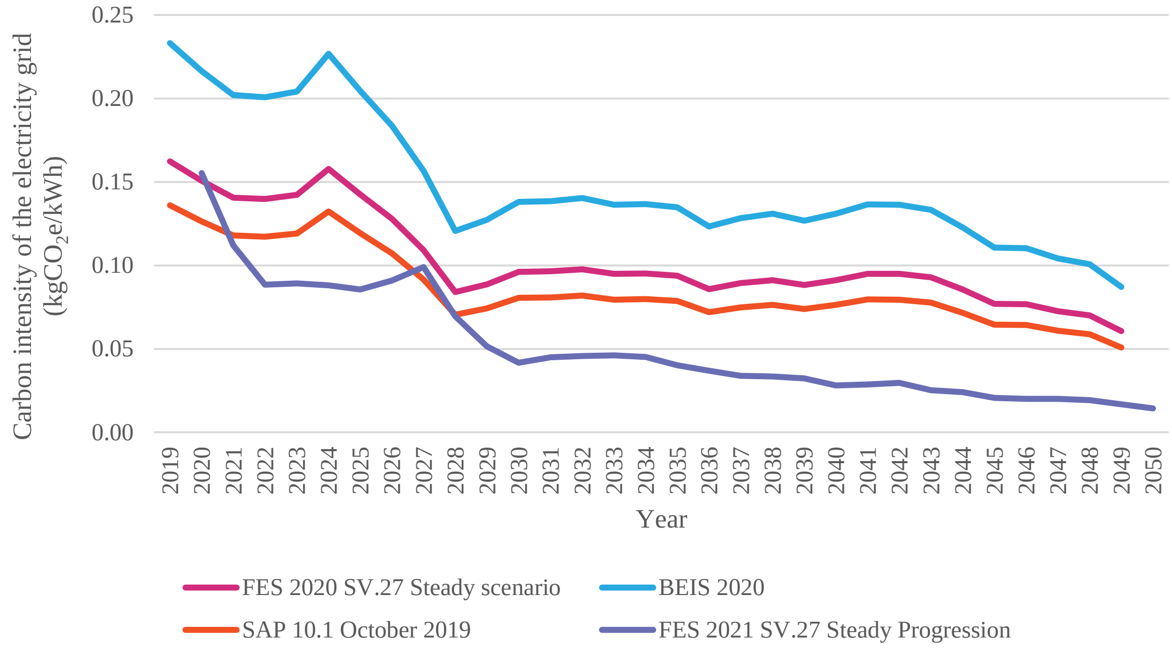


Figure 5: Projections for carbon intensity of UK electricity grid.

The total whole life carbon figure for the baseline model **with grid decarbonisation** is approximately **173,000 tCO2e** (equivalent to 1,357 $kgCO_2e/m^2$), a 15% carbon reduction compared to the value without decarbonisation, as shown in Figure 4. When grid decarbonisation is allowed for, the progressively lower carbon intensity of energy over the building's design life means that the embodied carbon emissions (i.e., those associated with materials) account for a greater proportion of the development's Life Cycle emissions (81% vs. 62% when decarbonisation is not accounted for).

The MEP engineers have advised that next steps for further operational carbon reductions include, but are not limited to:

- Analysis and refinement of free cooling operation and controls
- Optimising heat pumps and thermal stores controls/operation
- Optimising blind operation
- Optimising ventilation controls
- Relaxing temperature bands
- Mitigating tenant impact on HVAC, small power and lighting
- Accounting for out-of-hours use

A carbon reduction options assessment has been performed excluding decarbonisation. The whole life carbon emissions for the development over a 60-year life cycle, excluding grid decarbonisation, are summarised in Table 4. Allowances based on benchmarks and contingencies are also presented within this table, for completeness and comparability against future assessments. The **Stage 2 baseline whole life carbon impact** of the proposed development can be seen to be 1**,996** $\mathbf{kgCO_2e/m^2}$, equivalent to approximately 252,000tCO_2e.

Table 4: Whole life carbon (embodied and operational) results summary in accordance with RICS methodology and EN 15978. Values taken from benchmarks are presented in grey-shaded cells and contingencies are italicised.

$kgCO_2e/m^2$ GIA	Seq.	A1-A3	A4-A5	B2-B3	B4-B5	B6-B7	C1-C4	TOTAL (A-C)
Substructure		50	37	1			4	92 + *6*
Superstructure	-7	267	65	4	1		17	346 + *26*
Facade		105	17	15	31		2	171 + *8*
Int. walls and partitions		50	-	-	25		-	75
Int. finishes		70	-	-	125		-	195
FF&E		20	-	-	50		-	70
Building services		113	21	38	203	610	2	986
External works		10	-	-	10		-	20
TOTAL modelled	**-7**	**535**	**140**	**58**	**235**	**610**	**25**	**1,596**
+ benchmarks		**+ 150**			**+ 210**			**+ 360**
+ contingencies		***+ 38***					*+2*	***+40***
TOTAL (combined)								***1,996***

3.1.1 Contingencies and uncertainty

As appropriate for the early design stage, contingencies have been allowed for to mitigate the impact of the reliance on assumptions during early design development due to a lack of detailed material quantities at such an early stage. This reflects the expectation that further design development is anticipated to result in an increase in overall quantities for key materials, thus worsening the carbon intensity. To track and manage this process, the WLCA will be updated at each design stage.

3.2 Embodied Carbon Assessment (excl. operational carbon and grid decarbonisation)

This section assesses the key contributors to the development's embodied carbon both to practical completion and over a 60-year life cycle. The embodied carbon calculation to practical completion (EC-PC) comprises modules A1-A5 only. The life cycle figures (EC-LC) also include modules B (excluding B6-B7 operational energy and water) and C, known as the *in use* and *end of life* stages, respectively. Please see Appendix A1 for more information.

Owing to the early stage of assessment, contingencies have been agreed with the relevant disciplines in the design team to reflect the design stage. The following contingencies have been allowed for, and are clearly stated separately in the calculations and results:

- Concrete volume: +10%
- Steel reinforcement: +15%
- Structural steelwork (5% unknowns, 5% design): +10%
- Façade elements: +5%

Figure 6 illustrates the breakdown of embodied carbon over the building's lifecycle by building element modelled in OneClick. Allowances for building elements that could not be modelled due to lack of detailed information at this stage, and contingencies, are included as hatched regions in the figure.

Table 5 presents the embodied carbon impacts for all building element categories. The data demonstrates that the superstructure structural elements (predominantly frame and upper floors) constitute the greatest share of the building's embodied carbon. This is expected for high-rise buildings, owing to the larger vertical self-weight and lateral wind forces they must resist compared to mid-rise buildings. The impact of relatively high slenderness is also to increase the embodied carbon. The design team has identified several interventions to maximise the efficiency of the steel megaframe, in order to reduce steel tonnage during Stage 2. The superstructure frame embodied carbon to practical completion has in fact reduced considerably over the course of Stage 2, from 576kgCO_2e/m^2 at Stage 1+ to 379kgCO_2e/m^2 at the time of writing this report.

The relatively low carbon intensity of the substructure may be explained by the fact that, although more carbon is required for the substructure of high-rise developments in absolute terms, the proportion of GIA associated with the substructure of a high-rise development is typically smaller than that for a mid-rise. As the design develops, the assumptions can be refined.

Lean design principles should be explored in upcoming design stages to further reduce the carbon impact of the substructure and basement elements. An alternative substructure option is investigated in the options assessment presented in section 4.

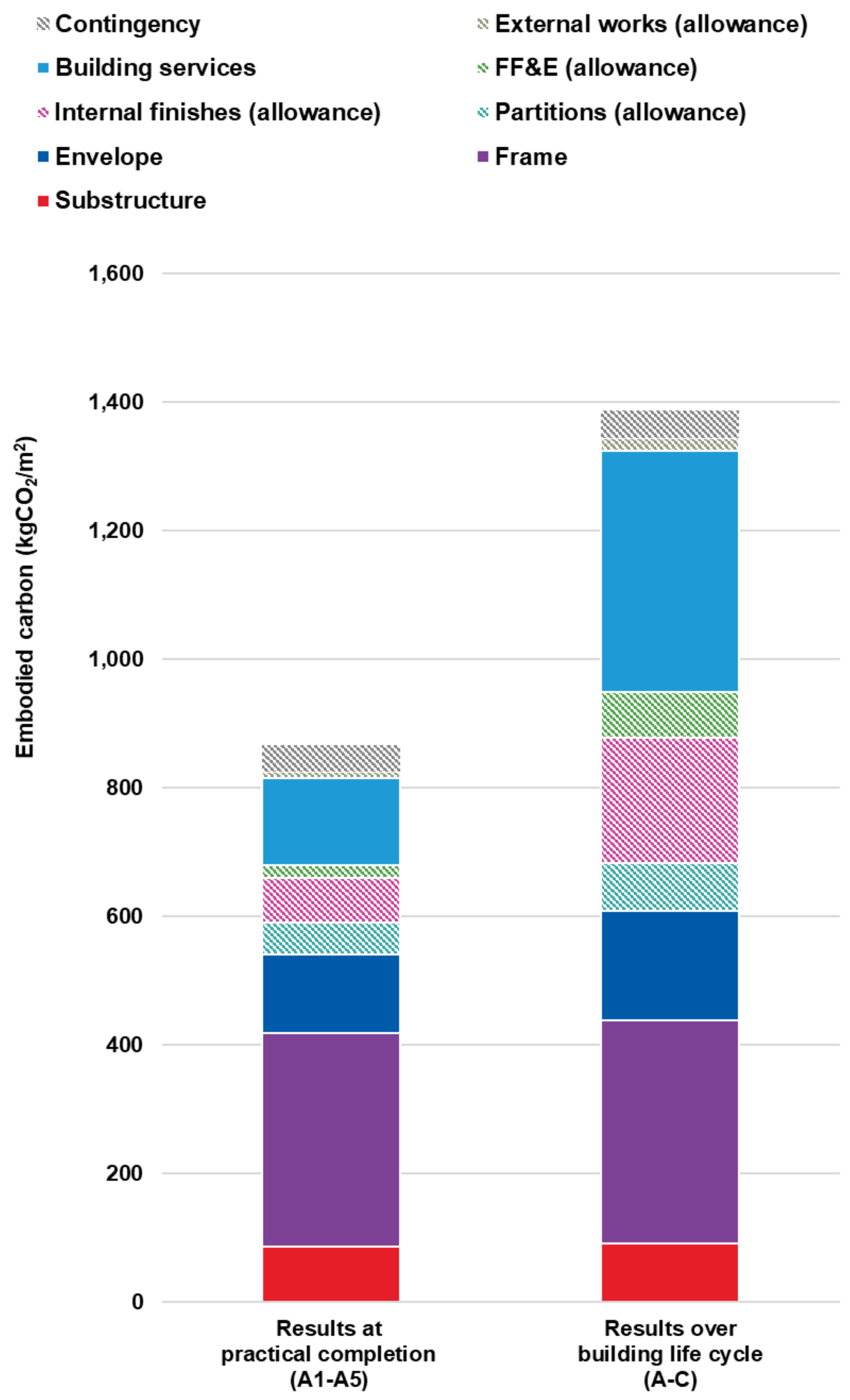


Figure 6: Breakdown of the embodied carbon emissions of the Stage 2 Baseline per building element to practical completion (A1-A5) and over life cycle (A-C). Allowances and contingencies marked by patterned fill as indicated in the legend.

Building services and façade are also major contributors to the overall embodied carbon of the development. Building services are generally assumed to be replaced every 15-30 years and this replacement frequency is captured in the life cycle proportions in Figure 7. The glass and blind motor used in the closed-cavity façade are assumed to be replaced every 30 years, while the megaframe is assumed to be permanent.

The industry benchmarks currently used for partitions, finishes, FF&E (furniture, fixtures and equipment) and external works are taken from the 'expected' range as they are not yet defined in sufficient detail to be modelled.

Table 5: Stage 2 Embodied Carbon emissions to Practical Completion (EC-PC) and over Life Cycle (EC-LC) per building element. Entries in italics are allowances based on GLA benchmarks. Contingencies are reported separately.

Building Element	EC-PC (A1-A5)		Contingency	EC-LC (A-C)		Contingency
	tCO_2e	$kgCO_2e/m^2$ GIA	kgCO2e/ m2 GIA	tCO_2e	$kgCO_2e/m^2$ GIA	kgCO2e/ m2 GIA
Substructure	10,987	87	+6	11,603	92	+ 6
Superstructure Structural	41,915	331	+26	44,636	346	+26
Superstructure Envelope	15,445	122	+6	21,619	171	+ 8
Int. Walls and Partitions	*6,323*	*50*		*9,486*	*75*	
Int. Finishes	*8,853*	*70*		*24,663*	*195*	
FF&E	*2,530*	*20*		*8,853*	*70*	
Building Services[1]	16,939	134		47,572	376	
Ext. Works	*1,265*	*10*		*2,530*	*20*	
TOTAL	**104,257**	**825**	**+38**	**170,962**	**1,345**	**+ 40**

Figure 7 illustrates the share of embodied carbon for the proposed development per life cycle stage, over the 60-year life cycle period, for the building elements modelled (excluding benchmarks and contingencies). According to this chart, a significant portion of the building's embodied carbon emissions is attributed to material production (modules A1-A3) and transportation (module A4).

The product stage, comprising modules A1-A3, focuses on the extraction, processing, and manufacturing of the materials ('cradle to gate') and therefore the initial selection of the materials is a key factor for reducing the CO_2e emissions of the development.

It should be recognised that the transport of equipment and materials (module A4) has been calculated in accordance with the RICS default figures (see Table 10) at this stage. This is because at this stage it is difficult to determine locations, distances and means of transport for each construction material and equipment that has been modelled. Consequently, the emissions which derive from stage A4 are indicative and must be reviewed and updated during construction.

Refer to appendix A2 for more details on how the A5 emissions have be calculated.

[1] Impact of services is based on ARUP's benchmarks due to lack of detailed quantities breakdown. Lifts modelled based on Alinea Stage 2 cost plan tracker.

Furthermore, as the design develops, the LCA model will reflect increasing granularity for the remaining in-scope building element categories, which have more frequent maintenance, repair and replacement cycles, the relative share of the B modules is expected to increase.

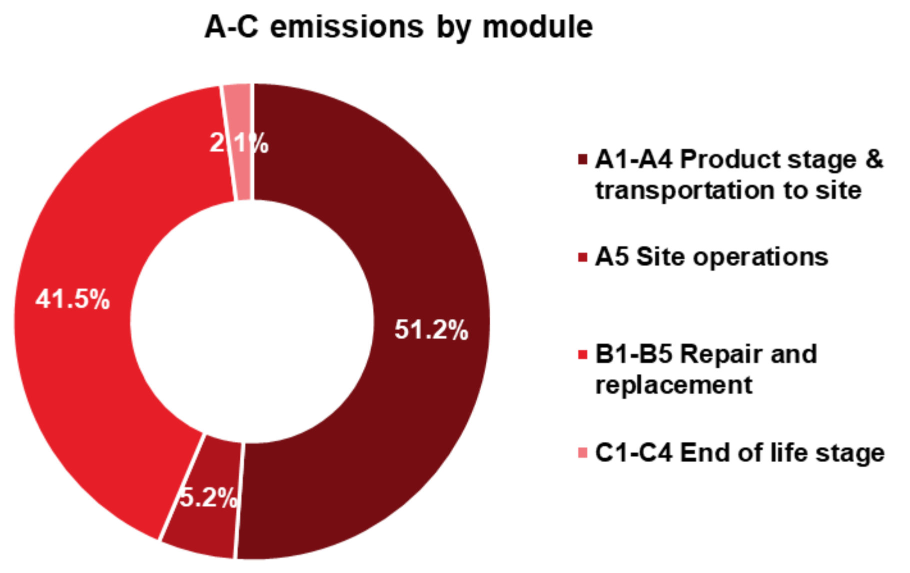


Figure 7: Breakdown of the embodied carbon emissions of the Stage 2 Baseline per life cycle stage (A-C). Considers only building element categories modelled in OneClick (i.e., no allowances) and no contingencies.

3.2.1 Superstructure comparison with the BREEAM benchmark

The baseline option for the RIBA Stage 2 design is assumed to be:

- Mat01_CD_SuperS_B

The Stage 2 baseline achieves 0 credits from the comparison with BRE's benchmark.

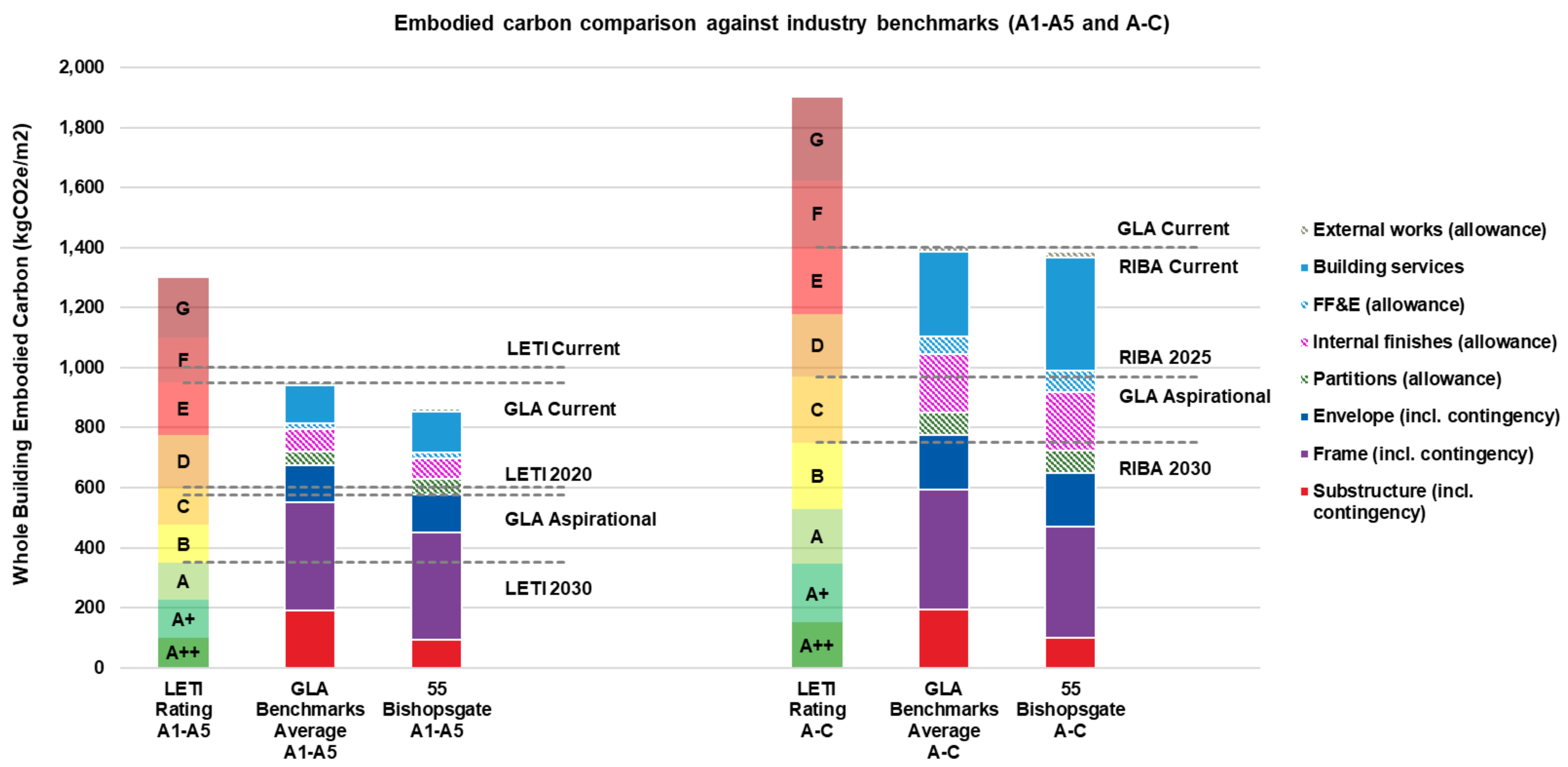


Figure 8: Whole building embodied carbon comparison against industry benchmarks (A1-A5, A-C).

3.3 High impact construction materials

This section provides a summary of the ten key construction materials that are responsible for the greatest CO_2 emissions of the development at practical completion. This only considers the modelled materials and does not include allowances or contingencies.

The key drivers of the CO_2 emissions shown in Table 6 are fabricated/standard structural steel sections and concrete, which are collectively responsible for over half of production stage emissions. This is as expected, due to the structural demands of a tall building.

Table 6 Construction materials with the highest embodied carbon at product stage (tCO_2e)

Material Category	Cradle to gate impacts (A1-A3)	
	tCO_2e	**%**
Fabricated structural steel sections	27,112	56.6
Concrete	13,107	
Standard structural steel sections	8,290	
Aluminium (CW frame, feature, venetian blind, ventilation louvre)	7,835	38.7
Reinforcement steel	5,795	
Electricity distribution system (cabling and central) - OneClick benchmark	5,167	
Electric elevators	4,012	
Galvanised profiled steel decking in composite floor slabs	3,825	
Ventilation system - OneClick benchmark	3,409	
Laminated safety glass	3,105	
Other	4,087	4.8
TOTAL	**85,744**	**100**

The pie chart in Figure 9 presents these results graphically and highlights how steelwork members are the major contributors to A1-A3 project carbon emissions (~41% of total), closely followed by the concrete frame elements – concrete and reinforcement steel (~22% of total).

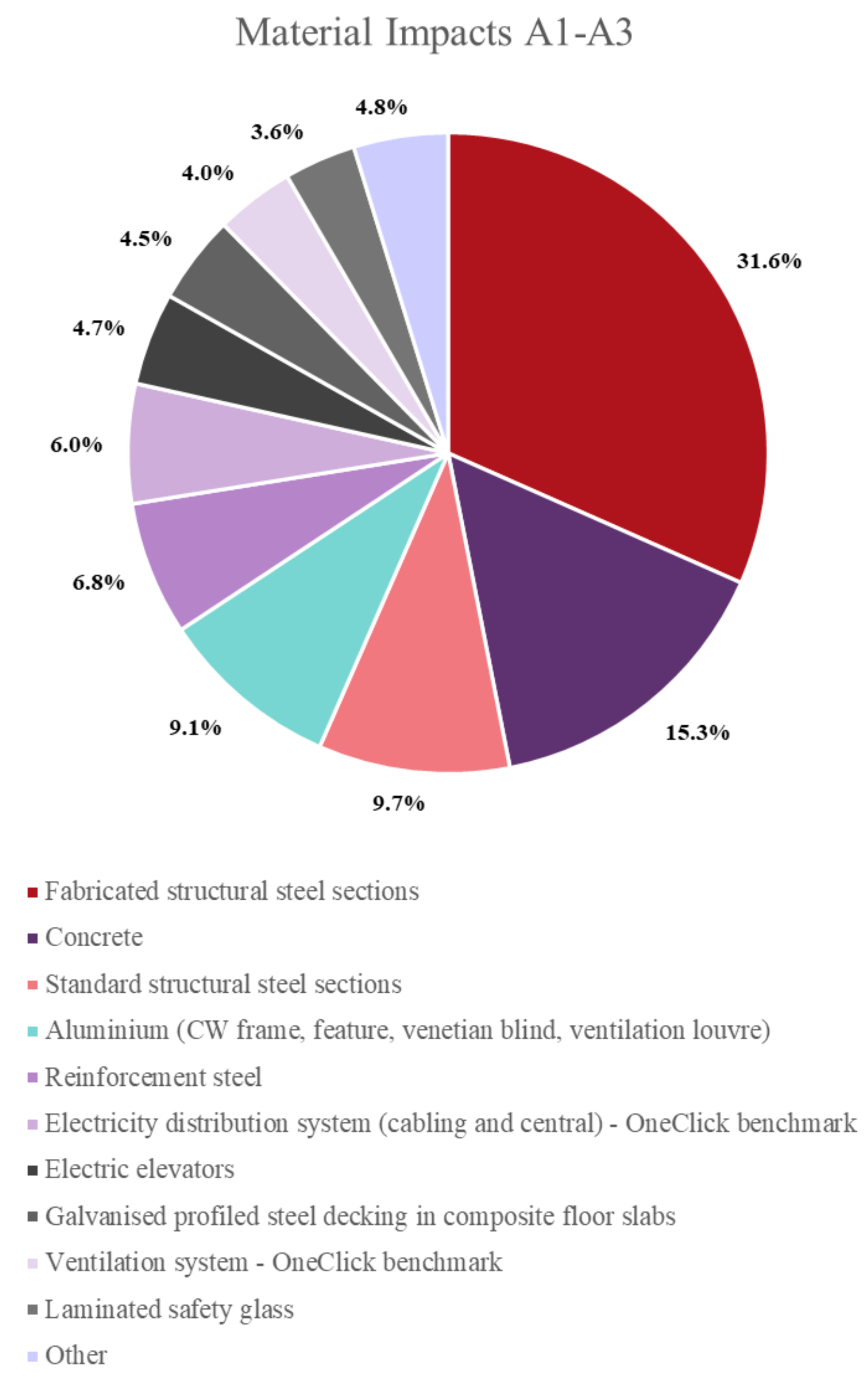


Figure 9: A1-A3 impacts by material on the proposed development.

3.4 Impact of demolition

This section estimates the potential carbon impact of the deconstruction of all or part of the building.

A pre-demolition audit of the existing building was carried out by Keltbray at the beginning of RIBA Stage 2. Full details of the pre-demolition audit can be found in the Appendix to the Circular Economy Statement submitted as part of this application.

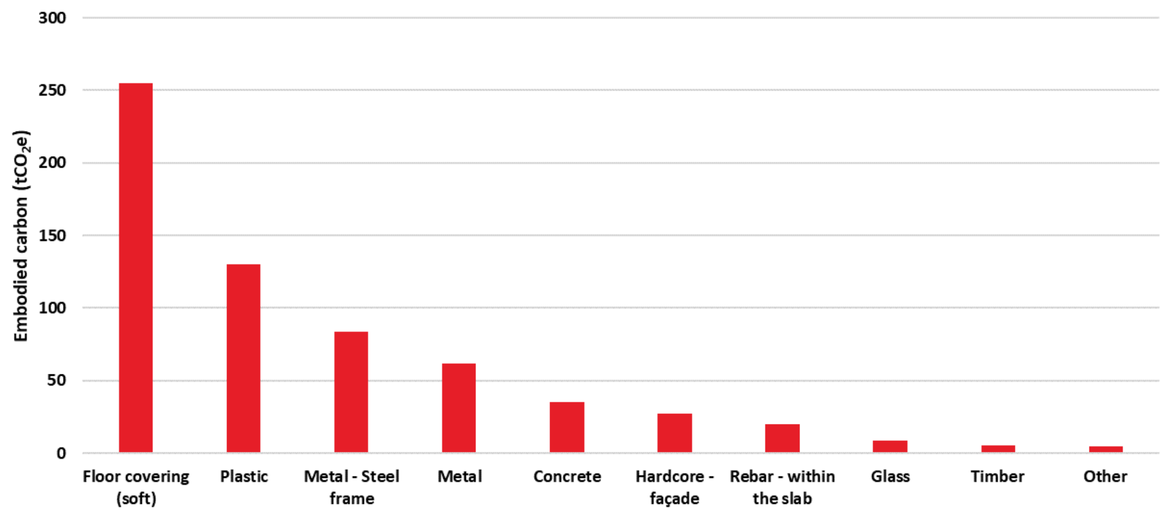
Table 7 summarises the output of this audit, quantifying the anticipated material tonnages alongside the estimated reuse and recycling rates for each of the key material streams. Keltbray provides an estimated reuse / recycling target of 100% for all demolition materials.

Table 7: Pre-demolition audit material quantities

		Estimated target (%)	
Waste / material type	**Tonnage forecast**	**Reuse**	**Recycling**
Metal	1,534	-	100
Tiles and ceramics	162	100	-
Floor covering (soft)	123	-	100
Timber	310	100	-
Gypsum	392	-	100
Insulation materials	60	-	100
Glass	228	-	100
Plastic	63	-	100
Miscellaneous / mixed demolition waste	321	-	100
Furniture	49	100	-
Concrete	10,559	100	-
Hardcore – façade	3,195	100	-
Rebar – within the slab	500	-	100
Metal – steel frame	2,080	-	100
Total	19,576		

The carbon impact of demolition has been calculated following the London Plan Guidance for Whole Life-Cycle Carbon Assessments, using actual figures provided within the pre-demolition audit. The end-of-life scenario is modelled using data provided by OneClick LCA, and all the material quantities identified in the table above were input using standard material specifications. The carbon impact of these materials can be seen in **Figure 10**.

Figure 10 Impact of demolition – Summary



The results demonstrate that the most carbon intensive demolition materials are floor covering, plastic and metal, together accounting for a majority of the total embodied carbon figure of 632 tCO_2e for the demolished building. These were included within the Stage 2 Baseline model as C1 deconstruction/demolition emissions.

The two largest contributors to demolition emissions, floor covering (soft) and plastic, were both modelled in OneClick LCA as plastic-based materials that are incinerated at their end-of-life. For example, floor coverings were modelled as carpet tiles, with a C3 emissions intensity of 2.07 $kgCO_2e/kg$. This accounts for their relatively high contribution to embodied carbon from demolition, despite their relatively small masses. Metals and rebar, which collectively contribute the next largest amount to embodied carbon from demolition, are modelled with an end-of-life stage being steel recycling. However, the largest share of these emissions (i.e., those from the electric furnace used to melt the steel) are part of module D and are therefore not assigned to this project. Concrete and hardcore are inert materials that require minimal end-of-life processing, mainly limited to concrete crushing. This explains their relatively low contribution to embodied carbon despite there being large quantities of these materials on site.

The existing building's GIA has been calculated to be approximately 27,500m^2, based on information provided in Appendix 1 of the pre-demolition audit. A total C1 impact of 23 $kgCO_2e/m^2$ has therefore been estimated for demolishing the existing building, which is lower than the GLA's estimated allowance of 50 $kgCO_2e/m^2$.

4 Options appraisal

The embodied carbon impact of several options for the superstructure, substructure and hard landscaping of the proposed development have been assessed to inform the Stage 2 design and propose next steps to reduce embodied carbon in further development of the design.

The comparative assessments have been undertaken in accordance with the BREEAM Mat01 requirements. The alternative design options were agreed based on the impact areas reported in the Stage 2 baseline embodied carbon model and the information on materials and quantities available from the design team in the timeframe of the study.

4.1 Superstructure options appraisal

Several significantly different design options were considered at RIBA Stage 2 to explore the reduction of the environmental impact of the superstructure. Four of these options have been used for the BREEAM options appraisal. These are explained in more detail in the following subsections and summarised in the table below.

Superstructure		Status
Option 1 Mat01_CD_SuperS_Opt1	Option 1 represents the baseline superstructure model at Stage 2 including perimeter steel megaframe, concrete cores and composite metal deck upper floors, with a double skin closed-cavity curtain wall façade. Option chosen.	✓
Option 2 Mat01_CD_SuperS_Opt2	Alternative steel megaframe and concrete core design, known as the ‘outrigger’ design.	✗
Option 3 Mat01_CD_SuperS_Opt3	Timber CLT replacing composite metal deck slabs on alternate floors.	✗
Option 4 Mat01_CD_SuperS_Opt4	Single skin façade replacing the double skin façade.	✗

Based on the above, 2 credits are achieved at RIBA Stage 2 from the superstructure options appraisal.

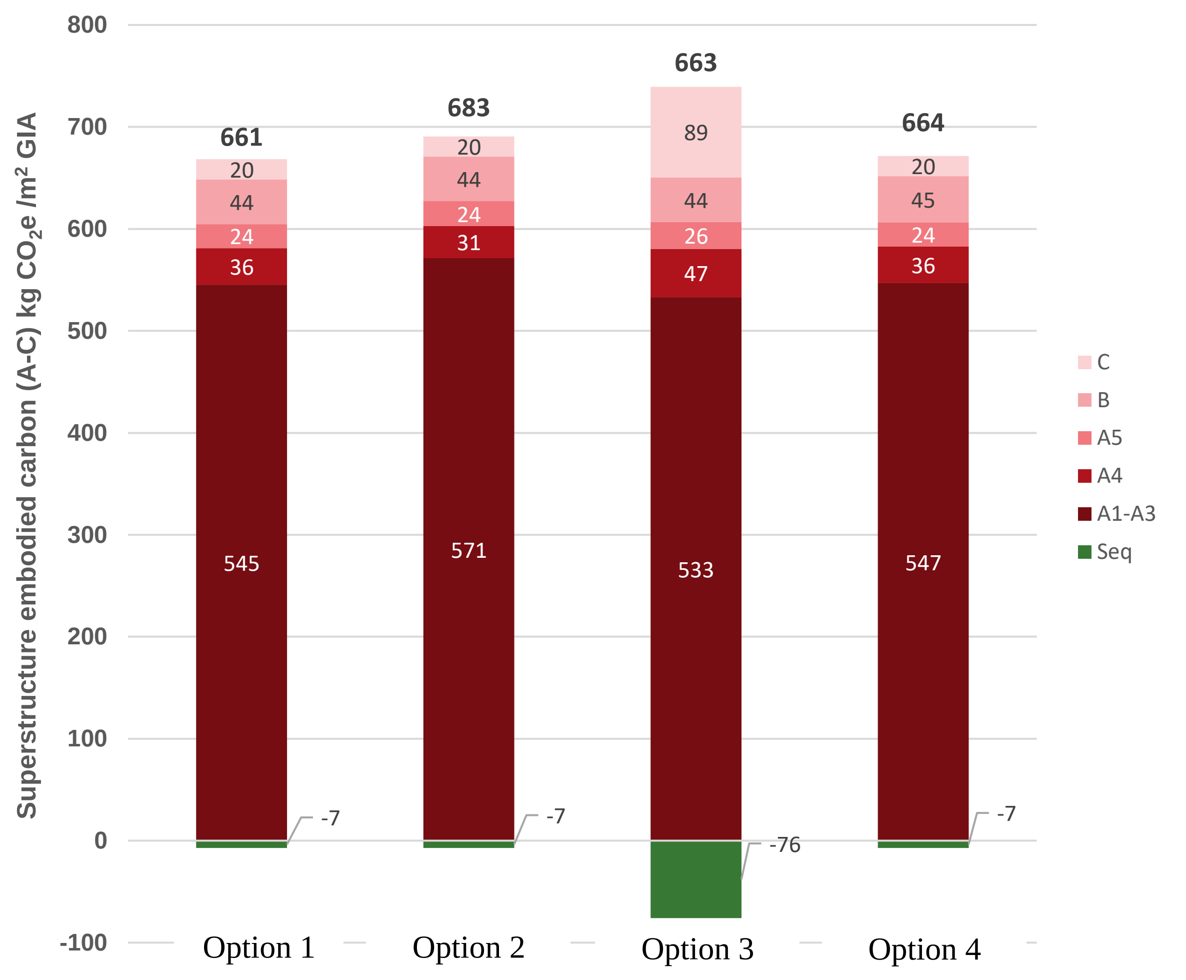


Figure 11 Comparison of embodied carbon for superstructure options

4.1.1 Superstructure option 2 – Alternative megaframe

RBG have explored an outrigger steel frame option during Stage 2 to compare key material quantities against the proposed design. It was concluded that the outrigger design would result in a steel saving and less reliance on fabricated steel sections for efficient material use but would require a large increase in concrete volume in the cores and foundations to achieve the same performance. It should be noted that the options assessment only considered the above ground structure of the outriggers scheme, due to the design stage, therefore the differences are expected to be underestimated.

The superstructure options assessment shows that this option comes with an embodied carbon cost (it would add 23kgCO_2e/m^2 GIA over the building lifecycle), which would be even greater if the additional concrete in the foundations and basement were considered, therefore it was not pursued further.

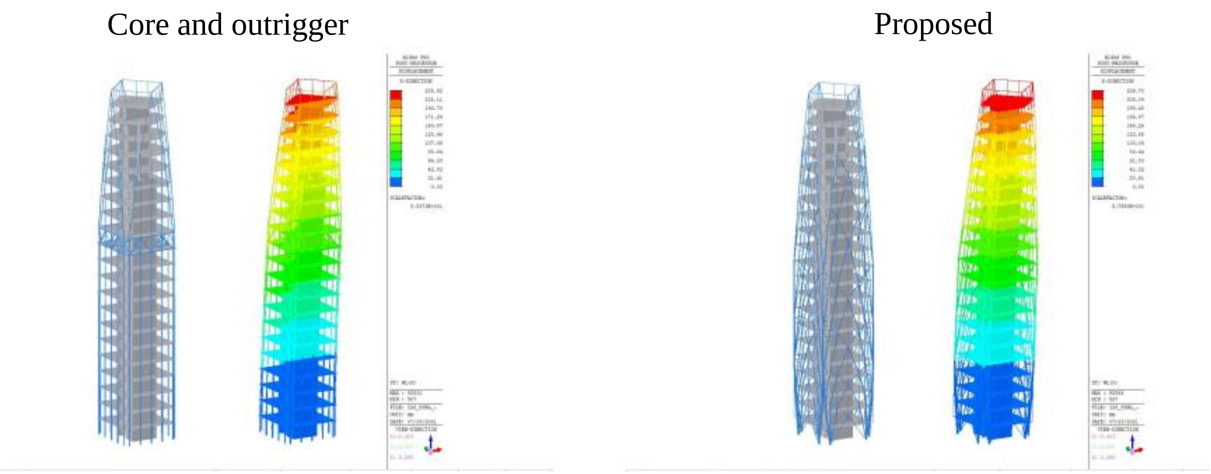


Figure 12: Outrigger and Proposed design options (provided by RBG).

4.1.2 Superstructure option 3 – Alternative floor slab design

RBG have proposed a timber infill option to the baseline floorplate design. This involves using CLT panels to replace the composite slab on alternate floors, to satisfy fire compartmentation requirements.

This option presents advantages including a lower total floor self-weight and thus building load on the foundations, leading to potential material savings for the vertical stability system (steel beams, concrete cores and foundations), as well as prefabricated components allowing for faster on-site assembly. It must be noted that the knock-on material savings have not been accounted for in this assessment, therefore the embodied carbon calculation is conservative.

However, this option would increase structural floor depths and consequently reduce floor to ceiling heights, and may require additional screed to increase acoustic impedance and limit vibrations. Moreover, only a few, large, mainland Europe-based CLT manufacturers would be able to provide such quantities, meaning the A1-A3 embodied carbon saving is outweighed by the greater A4 (transport-related) embodied carbon. The A5 (site emissions) embodied carbon impact is also expected to be higher than for the baseline composite floorplate as timber products have higher associated material wastage on site. However, these early-stage assumptions should be challenged at the next design stage, to see if these challenges can be resolved. Additional challenges of adopting the timber option include fire concerns and building insurance, especially with the lack of a precedent for such high-rise timber construction.

However, the floor slab design is an area where efforts should be focused in the next design stage to explore workable solutions to reduce embodied carbon, such as a composite concrete plank with CLT and concrete combined, or thin shell concrete.

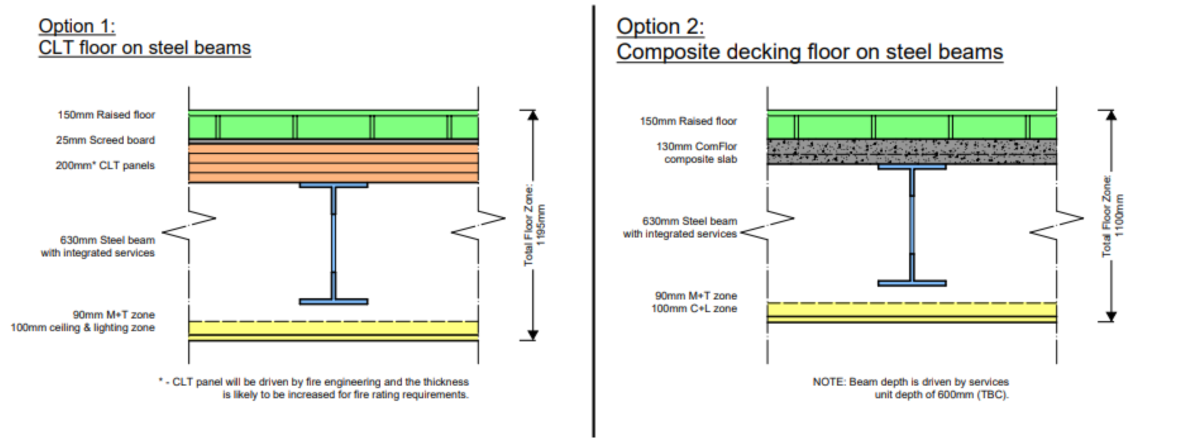


Figure 13: CLT vs composite decking floorplate build up (provided by RBG).

4.1.3 Superstructure option 4 – Alternative façade

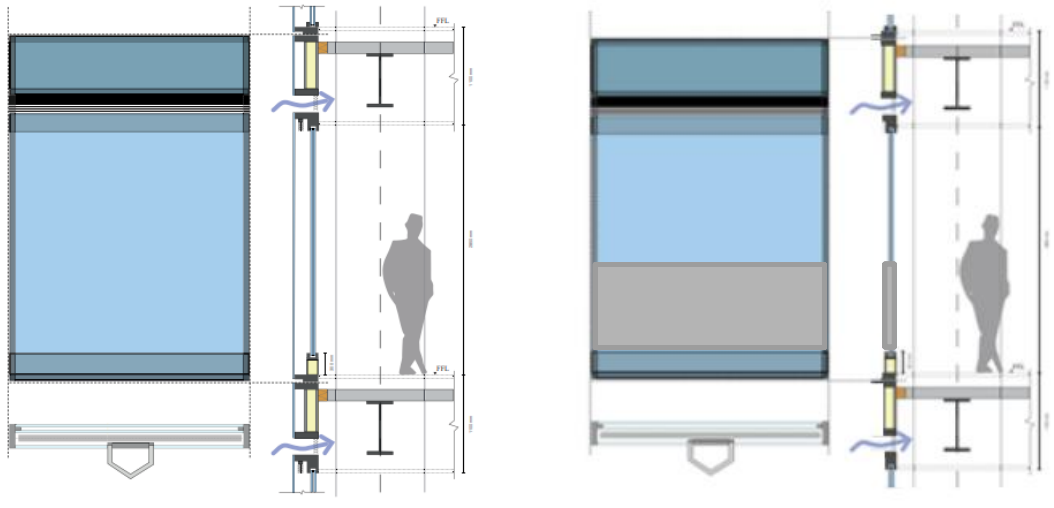
An analysis has been carried out comparing the baseline double skin façade with an alternative single skin design. It is worth noting that in both cases blinds will be required as with the single skin option, blinds will be required to deal with internal glare. With the double skin option, the blinds have a dual purpose of dealing with solar gain and internal glare.

The depth of the aluminium mullions would likely remain a similar depth due to the governing requirements of wind loading. Therefore, the primary variation is in the quantity of glass.

The double skin (closed cavity) façade system is built up from an inner double-glazed unit (DGU) and an outer laminated pane of glass. In contrast, the single skin system consists solely of the DGU layer. Although there is one pane of glass less, the greater thickness of these panes for the single skin option is likely to lead to an approximately 8% increase in the quantity of glass in the double skin. Although this is conservative estimate at this stage, it is likely that the overall thickness between the two options would remain comparable, in order to achieve the required structural performance.

As well as comparable embodied carbon performance of both of the options, there are several other factors which make the single option less favorable including increased operational carbon, increased solar gain, increased need for glare protection (i.e., blinds), less favourable glass replacement strategy and the construction complexities of ventilation and other system integration.

The solar gain targets have been tested on both single skin and double skin scenarios. The results showed a significant decrease in window to wall ratio would be required for the single skin solution. The resultant increase in opaque areas required would likely result in an increase in aluminium content on the single skin façade (either in the form of opaque spandrels and/or in the form of solar shading fins), which would significantly increase the embodied carbon of the façade further.



Double skin closed cavity façade (baseline) Single skin facade

Figure 14: Facade options considered.

4.1.4 Further superstructure opportunities

During the next design stage, the following further opportunities for embodied carbon reduction should be explored:

- Construction phasing for main core (i.e., jumpform vs. slipform) to inform a feasible, increased cement replacement for cores
- Quantification of knock-on savings of adopting the timber option, to assess whether this option is worth developing further from a carbon reduction perspective
- Additional alternative lower carbon floor slab designs
- Increased cement replacement levels for the floors, currently assumed at 50%
- Opportunities to procure ‘low carbon’ aluminium, from hydroelectric-powered manufacturing sources and with increased recycled content for various façade components
- Whether there is potential for procuring ‘second-hand’ steel members, particularly for secondary areas
- Assess realistic transport distances for actual site, rather than standard assumptions.

4.2 Substructure and hard landscaping options appraisal

Several significantly different design options were also considered at RIBA Stage 2 to explore the reduction of the environmental impact of the substructure (Figure 15) and hard landscaping (Figure 16). The appraisal includes 2 options for substructure and 4 options for hard landscaping. These are presented in the table below:

Substructure		Status
Option 1 Mat01_CD_SubS_HL_Opt1	Option 1 represents the substructure baseline, comprised of secant pile walls and pile raft foundation.	✓
Option 2 Mat01_CD_SubS_HL_Opt2	Option 2 represents the hard landscaping baseline consisting of Yorkstone paving.	✓
Option 3 Mat01_CD_SubS_HL_Opt3	Option 3 represents the substructure alternative option of limiting the secant pile wall thickness to 900mm. This reduces the concrete in the piles (secant and bearing) by approximately 10% but doubles the temporary works required for the substructure.	✗
Option 4 Mat01_CD_SubS_HL_Opt4	Option 4 represents the hard landscaping option of granite setts replacing the Yorkstone flags.	✗
Option 5 Mat01_CD_SubS_HL_Opt5	Option 5 represents the hard landscaping option of asphalt replacing the Yorkstone flags.	✗
Option 6 Mat01_CD_SubS_HL_Opt6	Option 6 represents the hard landscaping option of using recycled aggregates for the sub-base.	✗

Based on the above, 1 credit is achieved at RIBA Stage 2 from the substructure and hard landscaping options appraisal.

4.2.1 Substructure Option 3 – Alternative substructure

The analysis carried out demonstrates that reducing the secant pile thickness would result in an overall embodied carbon reduction, even when temporary works are doubled. However, due to the early design stage an allowance has been used for the temporary works, whereas it is likely to consist of a bespoke solution. The pursuit of this option would need to be considered in dialogue with pile and temporary works designers and contractors, as there are issues of life safety to consider, in addition to construction complexities.

Another approach would be to review the programme requirements of the basement. The design team would welcome further discussion with CoL regarding the requirements for cycle parking, and the embodied carbon impacts of basement construction compared with transport-related carbon impacts.

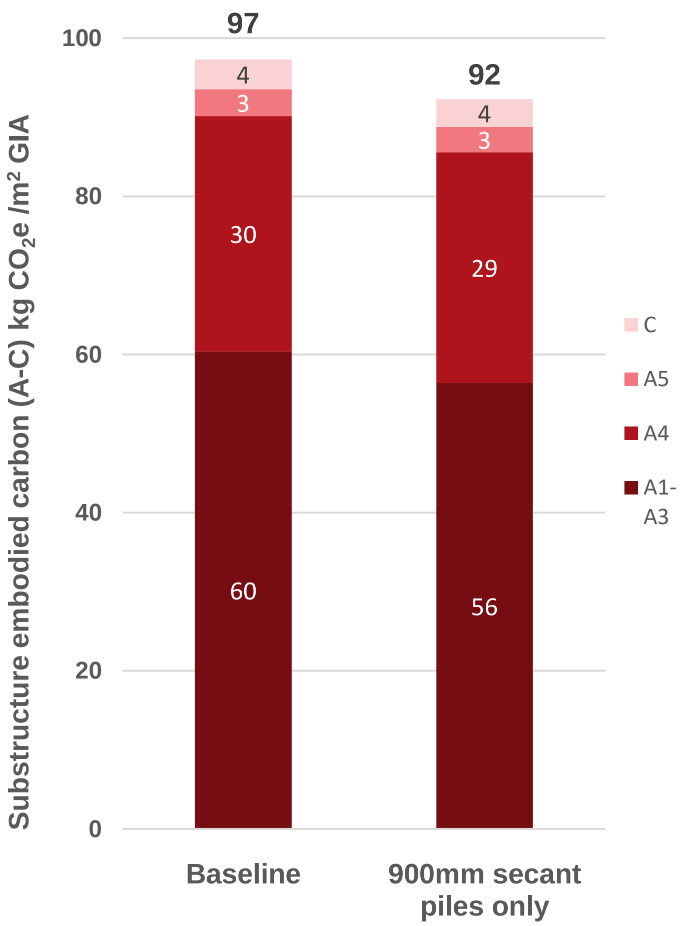


Figure 15 Comparison of embodied carbon for substructure options.

4.2.2 Hard landscaping Options 4-6 – Alternative finishes

The hard landscaping alternative options that have been considered are in line with the CoL requirements (as set out in the 'City Public Realm: Technical Manual'[2]). This comparison is very high level, as the hard landscaping design has not been progressed in detail due to the early design stage.

The results make it clear that granite setts have the highest impact, however the final solution is likely to include a hybrid solution of each of the materials. This will be refined further at the next design stage. Procurement 'second-hand' materials should definitely be considered.

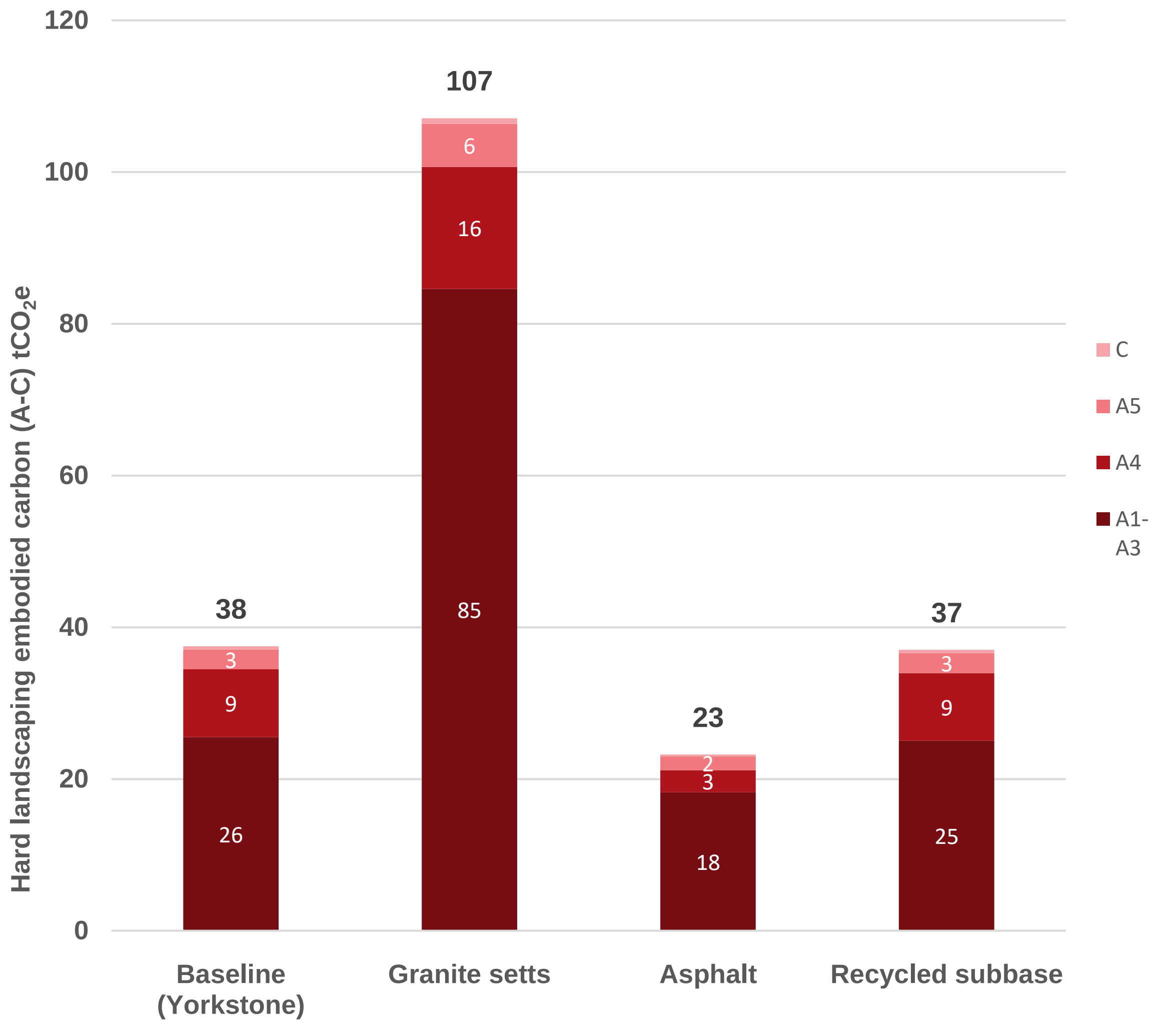


Figure 16 Comparison of embodied carbon for hard landscaping options

[2] https://www.cityoflondon.gov.uk/assets/Services-Environment/public-realm-technical-manual-2016.pdf

4.2.3 Further substructure and hard landscaping opportunities

During the next design stage, the following potential opportunities for carbon should be tested against the baseline;

- Further analysis of the opportunities for increasing temporary works, in conjunction with specialist contractors
- Consideration of the accommodation requirements of the basement, including the need for cycle parking.
- The potential for procurement of ‘second-hand’ hard landscaping finish materials, such as Yorkstone, granite setts and subbase.

4.3 Further opportunities for embodied carbon reduction

A summary of recommendations to reduce the embodied carbon of the proposed scheme is presented in Table 8 below. Baseline specifications are based on average industry standard practice due to lack of detailed information at RIBA stage 2. However, the baseline specification for the steelwork is based on the intended procurement of ArcelorMittal HISTAR steel (0.52 $kgCO_2e/kg$ A1-A3) for rolled sections. This specification was proposed for adoption by Robert Bird Group, and confirmed by the Client, during Stage 2.

The Quantity Surveyor should be consulted for the potential cost implications of each specification if these are adopted in the design. The alternative design options listed in Table 8 were agreed based on the impact areas reported in the stage 2 baseline embodied carbon model and the information on materials and quantities available from the design team in the timeframe of the study.

Table 8 Alternative designs modelled and resulting savings in embodied carbon at practical completion (EC-PC) and over the building's life cycle (EC-LC, 60 years)

			Stage 2 Baseline	Stage 2 Potential Options	Savings EC-PC		Savings EC-LC	
#	**Level 1 Group Element(s)**	**Level 2 Group Element(s)**	**Assumptions**	**Assumptions**	**$kgCO_2e$**	**%**	**$kgCO_2e$**	**%**
1	Superstructure	Windows and external doors.	Interstitial blinds, full depth.	Interstitial blind depth reduced by 20%.	324,565	**0.3%**	324,565	**0.2%**
2		External walls.	Feature material: Aluminium extruded profile.	Feature material: Hydro 75R Aluminium.	406,880	**0.4%**	406,880	**0.2%**
3		Frame.	Steelwork quantities as provided by Robert Bird Group (RBG). ArcelorMittal HISTAR high recycled content steel adopted for rolled sections (RBG steelwork scenario 5).	ArcelorMittal Xcarb steel (0.33 $kgCO_2e/kg$ A1-A3) used for tower megaframe, tower secondary columns/hangers, and satellite columns/diagonals (RBG steelwork scenario 9).	2,492,047	**2.3%**	2,492,047	**1.46%**
4		Upper floors including balconies.	Floor concrete C30/37.	Floor concrete C28/35.	212,810	**0.2%**	212,810	**0.1%**
5	Superstructure & substructure	Frame and substructure.	Floor slab: Ready-mix concrete 20% GGBS.	Floor slab: Ready-mix concrete 40% GGBS.	605,501	**0.6%**	605,501	**0.4%**
				TOTAL SAVINGS	**4,041,803 (32 $kgCO_2e/m^2$)**	**3.7%**	**4,041,803 (32 $kgCO_2e/m^2$)**	**2.4%**

5 Conclusions

The following conclusions can be drawn from this study:

- The Stage 2 embodied carbon footprint of the proposed development at Practical Completion (EC-PC) is approximately **109,000 tCO_2e (863 $kgCO_2e/m^2$ GIA)**. If contingencies are excluded the figure is approximately 825 $kgCO_2e/m^2$ GIA.
- The embodied carbon over its life cycle (EC-LC, 60 years) is approximately **175,000 tCO_2e (1,385 $kgCO_2e/m^2$ GIA)** and this accounts for approximately 70% of the building's whole life carbon, not accounting for decarbonisation.
- This embodied carbon performance falls within the GLA benchmark range for embodied carbon intensity, however sits outside of the GLA 'aspirational' range. It falls within Band E of the LETI carbon rating scheme for both A1-A5 and A-C.
- Several carbon reduction options have been tested against the baseline assessment, with an estimated whole-life embodied carbon saving of approximately 32 $kgCO_2e/m^2$ GIA (A-C) when all options are combined. Further opportunities will be investigated at the next stage.
- This assessment should be read alongside the Circular Economy Statement which has also been prepared for the planning application of the proposed development.

5.1 Next steps

Arup foresee the following potential steps to minimise embodied carbon:

- Procurement of low carbon steel will be prioritised in order to ensure that the savings it generates can be realised.
- Where the carbon reduction options tested are showing a potential saving, such as in the floor slab design and the substructure design, further analysis and assessment should be carried out at the next design stage.
- Further design development should be carried out on the floor slab design, to examine the integration of CLT slabs, either alone or in composite with other materials. The full material savings of this should be considered, including potential reductions to the frame and substructure material quantities, acknowledging the various technical risks associated with delivering this solution (including fire and insurance risks).
- In addition, the accommodation requirements and design of the basement should be considered, including an open discussion about the high number of cycle spaces in basements.

5.2 BREEAM Mat 01 score

All embodied carbon results have been extracted from the OneClick LCA tool in Excel spreadsheet version and linked to the BREEAM Mat 01 reporting tool (current version 2.2) to calculate the credits achieved for RIBA Stage 2. For the options comparison, the 'OneClick LCA (LCA for BREEAM UK)' materials database was used. Although this database is not IMPACT-compliant, the OneClick tool is IMPACT-compliant, so it can be used for the BREEAM Mat 01 options appraisal credits.

Overall, the number of BREEAM Mat 01 credits achieved at RIBA Stage 2 for the proposed development are summarised in Table 9 below:

Table 9 BREEAM Mat 01 credits achieved at RIBA Stage 2

	Benchmark comparison	**Options appraisal**	
	Superstructure	Superstructure	Substructure & hard landscaping
Concept Design	0	2.67	1

Further LCA modelling of the superstructure is required at RIBA Stage 4. Three more significantly different[3] superstructure options must be appraised to finalise the benchmark comparison credits and also to award additional credits for the options appraised.

[3] During Technical Design, different options are typically at the product level (within elemental constructions established during Concept Design). For instance, for element '3. Roof', option 'A' has a one type of insulation and option 'B' has another type of insulation.

Appendix A - Methodology

A1 Life Cycle Assessment (LCA) background

The purpose of an LCA is to assess the embodied environmental impacts associated with the building's resource demand over its whole life cycle to effectively investigate ways of reducing it. ISO 14040:2006 describes LCA as:

"addressing the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal."

One such environmental impact is the total global warming potential (GWP) associated with the extraction, manufacture, transportation, construction replacement and end of life use of the building's materials, more commonly referred to as the embodied carbon (expressed in $kgCO_2e$, or kilograms of carbon dioxide equivalent emissions), which is the key focus of the LCA for this project. This study does not look at the operational energy and water use.

The whole life cycle of the materials used in a building can be broken down into different life cycle stages, as described in Figure 17 below.

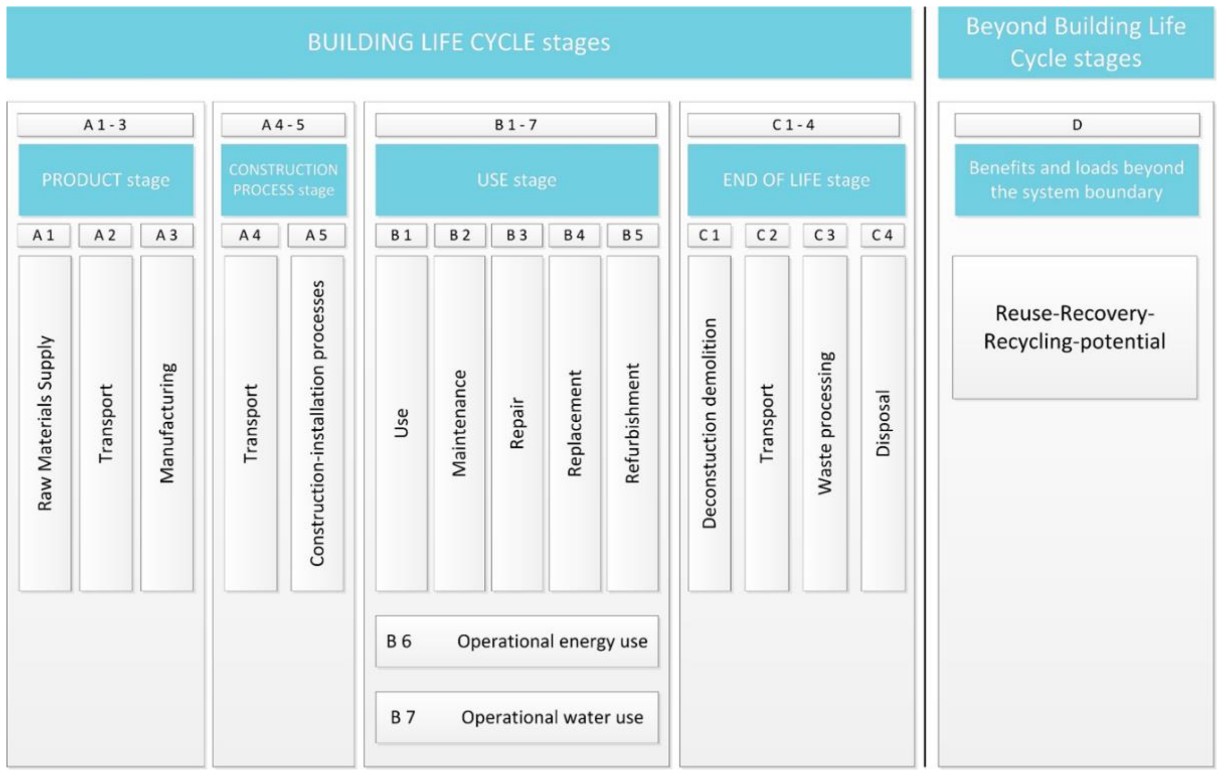


Figure 17: Building life cycle stages as defined in BS EN 15978: 2011

Information from an LCA allows the different building design disciplines to understand their influence on the environmental impact of the building and find holistic design solutions to minimise it.

A2 LCA best practice – RICS guidance

BS EN 15978:2011 is the European standard for 'Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method'. It provides the framework for appraising the environmental impacts of the built environment. This standard had been subject to varying interpretations by professionals across the construction industry.

To provide a consistent approach to the practical application of this standard, RICS (Royal Institution of Chartered Surveyors) published a document named 'Whole life carbon assessment for the built environment' in November 2017, and it is widely considered as best practice to follow this guidance in the UK. This LCA follows this RICS guidance where possible and where appropriate. Specifically, this guidance has been followed when considering:

- Material types not specified by the project team at RIBA Stage 1+ (these are highlighted where applicable throughout the report)
- Transport distances (affects module A4). The fourth column in the table below lists the materials in this LCA that are assumed to fall within each transport category:

Table 10 RICS default transport distances and assumed materials that apply to each category

Transport scenario	km by road	km by sea	Materials/products assumptions
Locally manufactured	50	-	Concrete, aggregate, sand, asphalt
Nationally manufactured	300	-	Structural steel, reinforcing steel, secondary steelwork, plasterboard, cement board, insulation, natural stone
European manufactured	1,500	-	CLT, façade cladding (aluminium, glazing, coatings), galvanised steel deck, geotextile
Globally manufactured	200	10,000	-

- Building elements expected lifespan (affects stages B4 & B5):

Table 11 RICS default element lifespans

Building part	Element	Expected lifespan (years)
Roof	Roof coverings	30
Superstructure	Internal partitioning and dry lining	30
Finishes	Wall finishes: Render/Paint	30/10 respectively
	Floor finishes: Raised Access Floor (RAF)/Finish layers	30/10 respectively

Building part	Element	Expected lifespan (years)
	Ceiling finishes Substrate/Paint	20/10 respectively
FFE	Loose furniture and fittings	10
Services/ MEP	Heat source, e.g. boilers, calorifiers	20
	Space heating and air treatment	20
	Ductwork	20
	Electrical installations	30
	Lighting fittings	15
	Communications installations and controls	15
	Water and disposal installations	25
	Sanitaryware	20
	Lift and conveyor installation	20
Façade	Opaque modular cladding	30
	Glazed cladding / curtain walling	35
	Windows and external doors	30

Construction site impacts (module A5) are made up of carbon emissions associated with site operations and with material wastage on site. Due to the early stage of the assessment, the RICS default embodied carbon factor for site operations (as opposed to the OneClick LCA default factor of 30.34 kgCO2e/m2 GIA) of 1,400 kgCO2e/£100k[4] project value is being used as the worst-case scenario. This is understood to not include the contribution from material wastage on site, which is instead calculated based on material specific RICS default site wastage rates or OCLCA data.

The site operation emissions for each RICS building element modelled have been calculated by applying the aforementioned RICS factor to the cost of the building element (taken from the Alinea Indicative Order of Cost Estimate dated 24.01.2021). Where lack of detailed building element information at this stage means these cannot be modelled explicitly and therefore benchmarks must be used, it is assumed that the site operation emissions are included within the A1-A5 benchmark values.

[4] Section 3.5.2.2, RICS Whole life carbon assessment for the built environment

A3 B module reporting

B2 and B3 emissions have been estimated in line with the methodology outlined in the new LPG Whole Life-cycle Carbon Assessments, section 2.5.12.

OneClick LCA have confirmed that it is not currently possible to separate the results of B4 and B5, therefore in this report they have been combined.

A4 LCA tools & data

The tool used to conduct this LCA is OneClick LCA, provided by Bionova. This software provides access to a large database of EPDs and ‘generic’ materials.

Sources of project information used in this study, such as material types quantities, are project documentation as listed in Appendix B1, along with a number of additional clarifications and verification of assumptions via email and discussion during an initial meeting and embodied carbon assessment workshop.

A5 Study limitations

There are several limitations of this LCA study that should be noted:

- It is based on the latest cost plan information provided by the cost consultant and Stage 2 information provided by the design team. Where information on material quantities, modes, distances of transporting the materials, lifespans and material specification is not known, the RICS default material information is used (see Appendix B3).
- The scope of this study is A-C, i.e. emissions at practical completion (modules A1-A5) and over life cycle (60 years lifespan, modules A-C). It does not account for module D (reuse, recovery, and recycling potential). Nor does it address deconstruct-ability and reusability of the materials and building elements considered.
- The impact of MEP services has been based on Arup’s benchmarks due to the limited access to a detailed breakdown of materials.
- The impact of partitions, finishes, FF&E and external works has been taken as the GLA ‘high’ benchmark value adjusted for high-rise developments, owing to the lack of detailed information for these building element categories.
- The new development will require the demolition of the existing 6-storey block on site, which has been accounted for separately, based on the RICS factor for this. The carbon impact of this has been estimated to be approximately 72,658 kgCO_2e.
- The B3 impact is assumed as an additional 10% over the building element lifespan for building services, facades, finishes and internal partitions. The B2 impact is assumed to be 4 x B3 impacts, as per RICS guidance.

Appendix B - Model basis

B1 Reporting requirements

Date of assessment	7th September 2022
Verified by	OneClick LCA
Project type	New-build office
Assessment objective	Embodied carbon assessment at practical completion and over life cycle of 55 Bishopsgate aiming to reduce its carbon footprint through low design options assessment.
Project location	City of London
Date of project completion	2030 (estimated)
Property type	New-build
Building description	Development consisting a main tower building, with 64 storeys above ground and 3 levels of basement, and an adjacent satellite tower. Hybrid steel megaframe and concrete core structural arrangement, with composite metal deck floorplates, overlaying a reinforced concrete basement and piled foundations.
Size	m^2 — NIA / GIA Office — 77,162 / 126,477
Project design life	60 years
Assessment scope	Substructure Superstructure Finishes Building Services External works Product stage [A1-A3] Construction process stage [A4–A5] Use stage [B1-B5] End of Life [C1-C4]
Assessment stage	RIBA Stage 2
Data sources	OneClick LCA library IMPACT database Environmental Product Declarations (EPDs) 55BG Fibonacci Alinea Cost Plan (24th February 2021) Arup Facades Input Volume spreadsheet (provided 11th November 2021) 4352-DN-S-001 Concrete Material rates (16th December 2021) 55BG Indicative Order of Cost Estimate - Theoretical Basement Rate Builder - Fibonacci Scheme (20th January 2022) Rober Bird Group Steelwork embodied carbon A1-A3 scenarios (provided 23rd August 2022)
Assumptions and scenarios	The Stage 2 model is based on the latest information received from the design team and the RICS default specifications for the main building materials when lack of detailed information.

B2 Process

The diagram below describes the process followed to conduct the RIBA Stage 2 LCA for the proposed development.

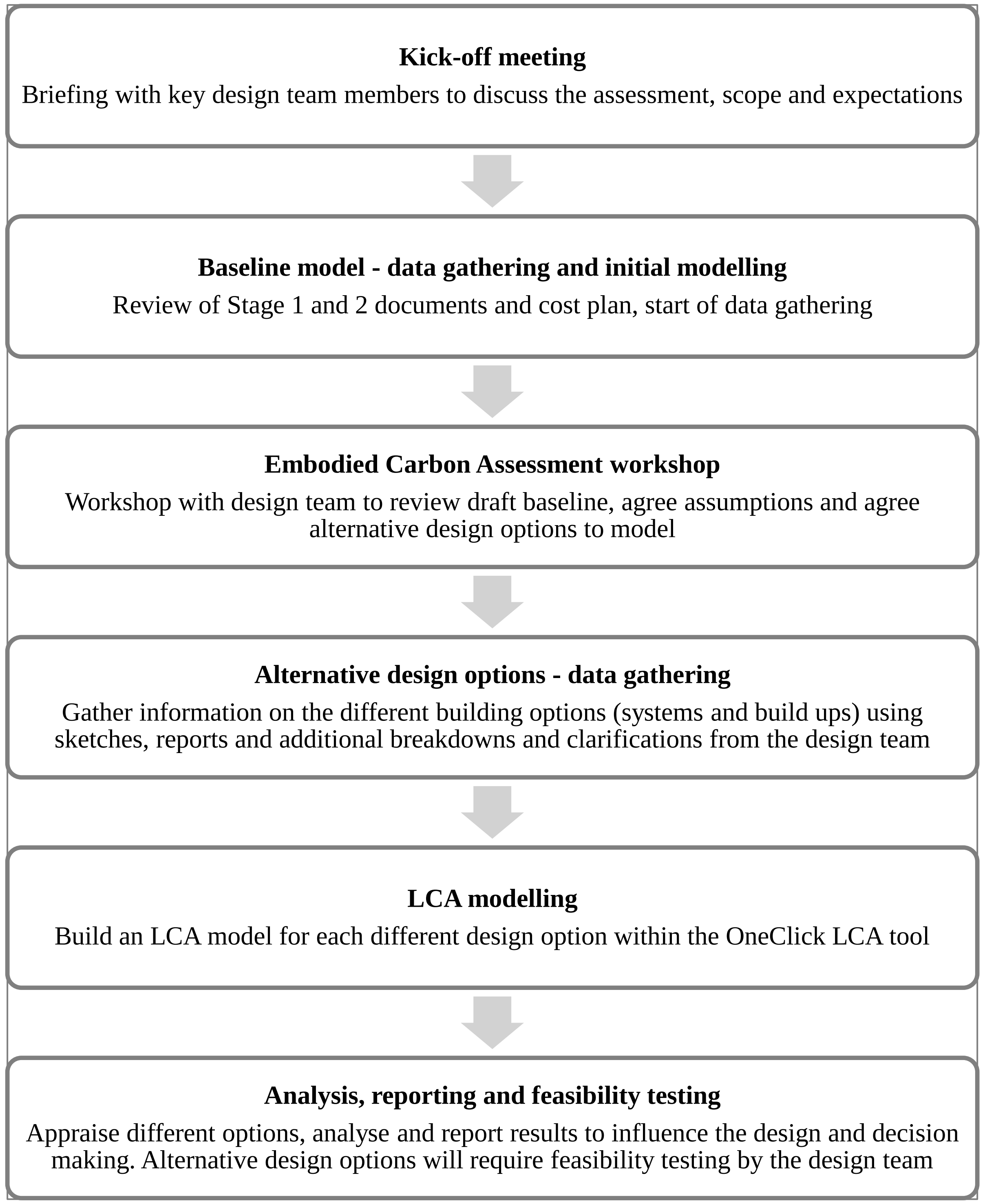


Figure 5 LCA process

B3 RICS scope

The scope of this analysis is to undertake a RICS-compliant LCA of the proposed development for RIBA Stage 2 (reporting on modules A-C). The following building elements fall within the scope of this LCA (where applicable):

Legend

Within scope
Within scope, based on benchmarks due to insufficient detail in cost plan information
Outside of scope

Table 12 RICS-complaint in-scope elements for the RIBA Stage 2 analysis

Level 1	Group element	Level 2	Element	Level 3	Sub-element
1	Substructure	1	Substructure	1	Standard foundations
				3	Lowest floor construction
				4	Basement excavation (fuel use only)
				5	Basement retaining walls
2	Superstructure	1	Frame (other than floors)	1	Steel frames
				2	Space decks
				3	Concrete casings to steel frames
				4	Concrete frames
				5	Timber frames
				6	Other frame systems
		2	Upper floors	1	Floors
		3	Roofs	1	Roof structure
				2	Roof covering
				3	Specialist roof systems
				5	Rooflights, skylights and openings
		4	Stairs and ramps	1	Stair/ramp structures
				3	Stair or ramp balustrades and handrails
		5	External walls	1	External enclosing walls above ground floor level
				2	External enclosing walls below ground level
				3	Solar or rain screening
				4	External soffits
		6	Windows and external doors	1	External windows
				2	External doors
		7	Internal walls and partitions	1	Walls and partitions
		8	Internal doors	1	Internal doors
3	Internal finishes	1	Wall finishes	1	Finishes to walls
		2	Floor finishes	1	Finishes to floors
				2	Raised access floors
		3	Ceiling finishes	1	Finishes to ceilings
				2	False ceilings
				3	Demountable suspended ceilings
4	Fittings, furnishings, and equipment (FF&E)	1	Fittings, furnishings, and equipment	1	General fittings, furnishings, and equipment
				3	Special purpose fittings, furnishings, and equipment
				4	Signs or notices
5	Services	1-14	Building services	1-14	Building-related services
6	Prefabricated buildings and building units	1	Prefabricated buildings and building units	6	Prefabricated buildings and building units
8	External works	1	Site preparation works	1	Site clearance
				2	Preparatory groundworks
		2	Roads, paths, pavings and surfacings	1	Roads, paths, pavings and surfacings
		3	Soft landscaping, planting and irrigation systems	1	Seeding and turfing
				2	External planting
				3	Irrigation systems
		4		1	Fencing and railings

Level 1	Group element	Level 2	Element	Level 3	Sub-element
			Fencing, railings, and walls	2	Walls and screens
				3	Retaining walls
				4	Barriers and guardrails
		5	External fixtures	1	Site or street furniture and equipment
				2	Ornamental features
		6	External drainage		
		7	External services		
		8	Minor building works and ancillary buildings		

At this stage, the cost plan does not specify internal partitions, finishes, FF&E and external works in sufficient detail for modelling. Therefore, these impacts have been based on GLA benchmark values. Similarly, MEP services are based on Arup's benchmark value from similar commercial projects as a detailed breakdown of materials and quantities was not available from the design team.

OneClick LCA provides several detailed datasets describing the environmental properties of constructions and materials resulting in a detailed output. The main construction materials used within the proposed development Stage 2 LCA are as per the Stage 2 Alinea cost plan tracker and RBG '4352-DN-S-001 Concrete Material rates' or, where insufficient detail has been provided, based on RICS default specification. In some instances, further clarification has been sought from the project team and/or professional judgement has been made. Please also refer to section 2.8.

Appendix C – Glossary of terms

BIM: Building Information Model (BIM) is a digital representation of physical and functional characteristics of a construction project. A BIM is a shared knowledge resource for information which helps to form a basis for decisions during the lifecycle of the construction project.

Carbon dioxide equivalent (CO_2eq): A measure used to compare the emissions from various greenhouse gases based upon their global warming potential in a common unit over a 100-year period. E.g. 1 kg of methane is converted into the amount of CO_2 needed to cause the same effect, in this case 23 kg. Therefore 1 Kg methane has a CO_2 equivalent of 23.

Embodied carbon at Practical Completion: Carbon emissions arising from the product stages (A1-A3) and construction process stages (A4-A5).

Embodied carbon over Life Cycle: Carbon emissions arising from the product stages (A1-A3), construction process stages (A4-A5), use stages (B1-B5) and end-of-life stages (C1-C4).

Environmental aspect: An aspect of construction works, part of works, processes or services related to their life cycle that can cause change to the environment.

Environmental impact: A change to the environment, whether adverse or beneficial, wholly, or partially, resulting from environmental aspects.

Greenhouse gas: Any atmospheric gas which absorbs thermal radiation emitted by the Earth's surface. This traps heat in the atmosphere and keeps the surface at a warmer temperature than would otherwise be possible.

Greenhouse effect: The greenhouse effect is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere.

Global Warming Potential (GWP): The standard metric used to calculate CO_2-equivalent emissions of different greenhouse gases in carbon budgets and the Kyoto Protocol. GWP measures the total radiative forcing over a given period (usually 100 years) after a pulse emission, relative to that from the same mass of CO_2.

IMPACT (Integrated Material Profile And Costing Tool): A specification and database for software developers to incorporate into their tools to enable consistent Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). IMPACT compliant tools work by allowing the user to attribute environmental and cost information to drawn or scheduled items in the BIM. Put simply, IMPACT takes quantity information from the BIM and multiplies this by environmental impact and/or cost 'rates' to produce an overall impact and cost for the whole (or a selected part) of the design.

Life cycle: consecutive and interlinked stages on the life of the object under consideration.

Life Cycle Assessment (LCA): is a process to evaluate the environmental burdens associated with a product, process, or activity:

- By identifying and quantifying energy and materials used and wastes released to the environment;
- To access the impact of those energy and materials used and releases to the environment; and
- To identify and evaluate opportunities to affect environmental improvements.

The assessment includes the entire life cycle (from cradle to grave) of the product, process or activity encompassing extracting and processing of raw materials, manufacturing, transportation, and distribution; use and re-use; maintenances; recycling and final disposal.

Life Cycle Costing (LCC): The cost of an asset, or its part throughout its cycle life, while fulfilling the performance requirements. Generally, LCC are those associated with the construction and operation of the building. The cost of operating and maintaining a building builds up over time and is significant when compared to the original capital cost of construction. LCC helps to demonstrate cost-effective design and to plan expenditure over the building life.

Operational energy use: Energy consumption of the building during its use and operation of the building.

Operational water use: Water consumption of the building as needed for the technically and functionally defined operation of the building.

Recycling: Recycling is the process of converting waste materials into new materials and objects. A recovery operation by which waste materials are reprocesses into products, materials, or substances either for the original purpose or other purposes.

Refurbishment: Modification and improvements to an existing building to bring it up to an acceptable condition.

Whole life Carbon: Overall embodied carbon and the carbon associated with the building's operation (heating, cooling, powering, providing water etc.). It comprises stages A1-A5, B1-B7, C1-C4 and D.