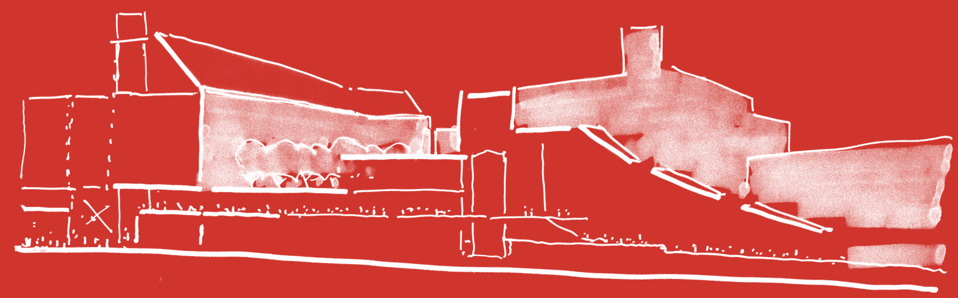
The British Library Extension

Stage 2 Life Cycle Assessment (LCA)



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British Library Extension

Stage 2 Whole Life Cycle Assessment

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Contents

Executive Summary

This document has been prepared on behalf of the British Library and SMBL Developments Ltd (Stanhope PLC and Mitsui Fudosan) as the 'Applicants' to support the applications for planning permission and listed building consent at the land to the north of the British Library ('the Site').

This report describes the RIBA Stage 2 Whole Life Cycle Assessment (WLCA) of the British Library (BL) Extension project ('the Proposed Development'), located in the London Borough of Camden. The analysis is in accordance with the RICS Professional Statement and aligns with BS EN 15978:2011.

This document supports the planning application submission through alignment with London Plan (2021) Policy SI 2 *Minimising greenhouse gas emissions*, which requires development proposals referable to the Mayor to calculate whole life carbon emissions. The report is structured according to the Mayor's draft guidance on WLCA reports. For more information, please see the completed GLA WLCA Template submitted as part of this application.

It additionally aligns with the London Borough of Camden Local Plan (2017) Policy CC1 *Climate Change Mitigation* and Camden Planning Guidance 'Energy Efficiency and Adaptation' (2021).

This assessment is reported according to the following scopes:

- Modules A1-A5: Emissions at practical completion
- Modules A-C: Emissions over the building life cycle (60 years)

See the Appendix for further details on reporting modules A-D.

Results

The Proposed Development has been modelled at Stage 2, with the core structure as follows:

- Substructure: Raft foundation with secant perimeter piling
- Transfer level frame: Concrete primary beams and columns, glulam secondary trusses
- Upper Floors: Concrete columns and beams, timber/concrete hybrid floor slabs
- Unitised façade system: Closed cavity façade (CCF) modules, double-glazed units, brickwork

Based on the current Stage 2 design, the assessment identifies the following:

- The Stage 2 embodied carbon footprint of the Proposed Development at practical completion (A1-A5) is approximately **56,546 tCO2e (635 kgCO2e/m^2 GIA).**
- The Stage 2 embodied carbon footprint of the Proposed Development over the building life cycle of 60 years (A-C) is approximately **97,070 tCO2e (1,089 kgCO2e/m^2 GIA).**
- The whole life carbon emissions of the Proposed Development are approximately **195,140 tCO2e (2,190 kgCO$_2$e/m^2 GIA)** over the building life cycle of 60 years (A-C). Within this figure, operational carbon accounts for **50.3%** of the total.

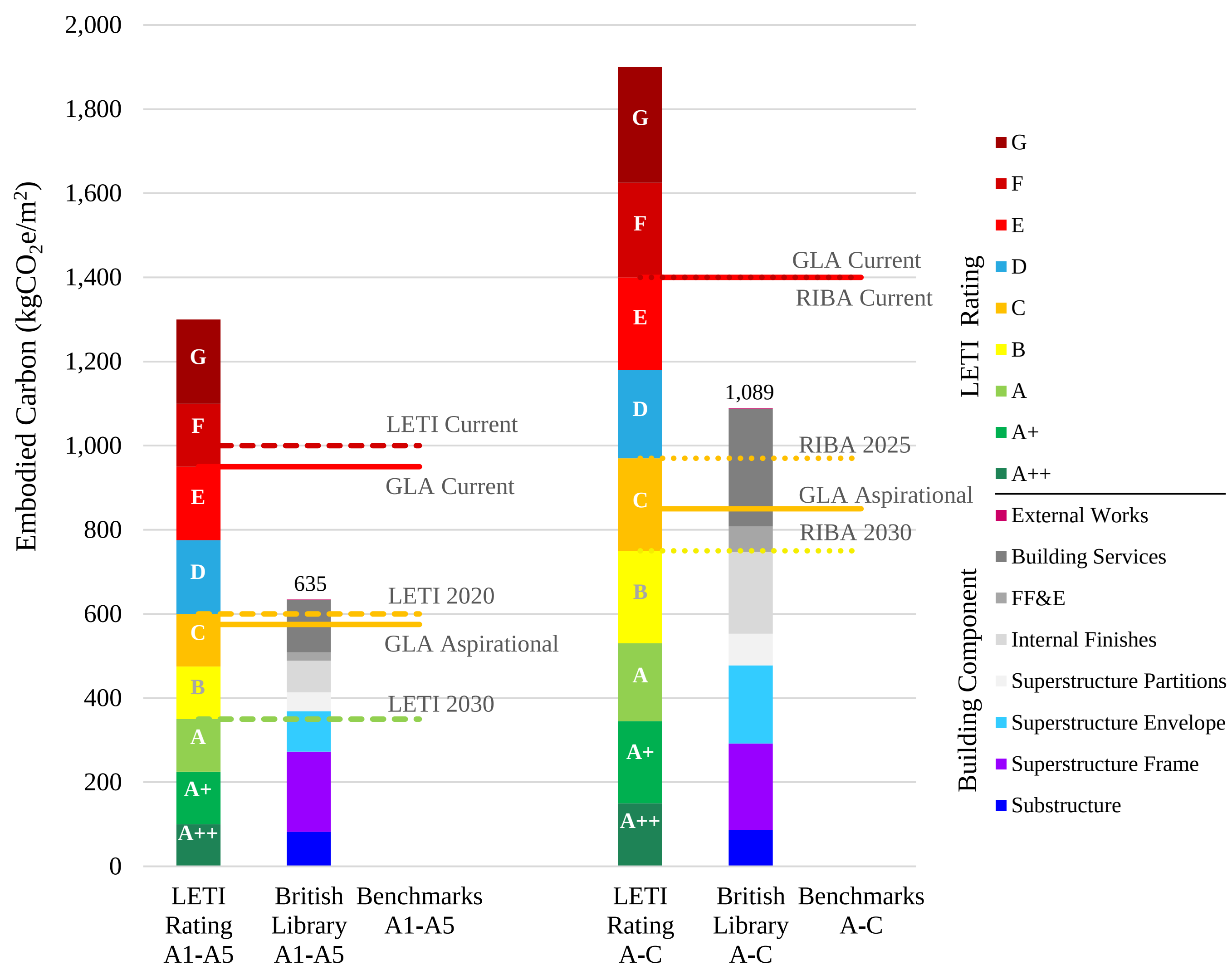


Figure 1 Baseline emission results for the proposed British Library Extension compared to GLA, LETI and RIBA benchmarks, at practical completion (A1-A5) and over the building life cycle (A-C).

Figure 1 shows the Stage 2 Baseline results at practical completion (A1-A5) and over the building life cycle (A-C). The Stage 2 Baseline results are compared to the following benchmarks:

- London Energy Transformation Initiative (LETI): Defines current practice benchmarks and targets for 2020 and 2030 (A1-A5 only)
- The Royal Institute of British Architects 2030 Climate Challenge (RIBA): Defines benchmarks and targets for buildings to aim to meet net zero over life cycle (A-C)
- Greater London Authority (GLA): The Whole-Life Carbon Guidance developed within the London Plan defines benchmarks and aspirational targets for buildings (A1-A5, A-C).

In the graph above, the grey areas represent the building components not detailed in the Stage 2 cost plan. In these cases, GLA office benchmark values have been used. It is important to note that while the GLA office benchmarks have been used, the Proposed Development incorporates lab-enabled office space. This requires stricter levels of specification in areas such as finishes and MEP specification, which will therefore increase the embodied carbon liability.

Stage 2 Optioneering

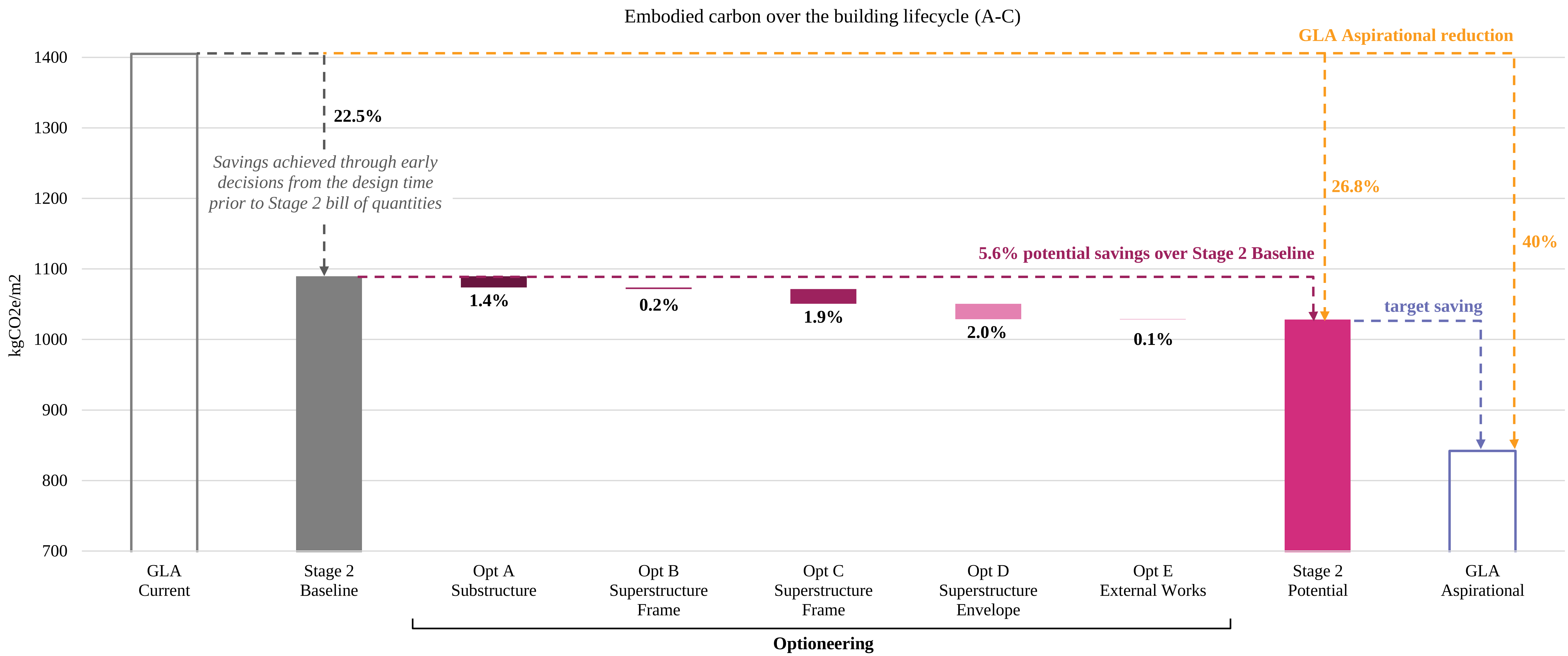


Figure 2 Waterfall graph showing the potential embodied carbon reduction from alternative design options, against GLA Current and GLA Aspirational targets over the building life cycle (A-C)

		Stage 2 Baseline		Stage 2 Potential	Savings (A-C) kgCO₂e	Savings (A-C) %
Substructure	Concrete elements	40% GGBS content in concrete mix	**A**	60% GGBS content in concrete mix	1,390,649	1.43%
Superstructure	Upper floors	CLT infills 40% GGBS content in concrete mix	**B**	CLT cassettes + concrete beams 40% GGBS content in concrete mix	205,492	0.21%
Superstructure	Upper floors	CLT infills 40% GGBS content in concrete mix	**C**	CLT infills 60% GGBS content in concrete mix	1,866,730	1.92%
Facade	Façade	Standard aluminium fins	**D**	20% recycled content in aluminium fins	1,918,705	1.98%
External works	Paving	381m^2 Permeable resin-bound aggregate, 128m^2 Concrete grass-crete, 320m^2 Parking asphalt, 2986m^2 Natural stone setts	**E**	Replacement of Natural stone setts (2986m^2) with Permeable resin-bound aggregate	55,222	0.06%
				Total Savings	**5,436,798**	**5.60%**

Table 1 Alternative design options and resulting embodied carbon savings over the building life cycle (A-C)

The Design Team took actions to reduce the project embodied carbon early on in the design process. Baseline material specifications that reduced the carbon footprint of the building before materials were quantified are therefore reflected in the cost plan used to calculate the Stage 2 Baseline impact.

For example, the baseline specification for concrete uses 40% GGBS content, which is significantly higher than typical values; the baseline design includes CLT components, which have reduced the weight of the structure and therefore the material volume of the substructure; and both the substructure and superstructure have been efficiently designed to overcome the challenges posed by the location of Crossrail 2 underneath the building.

All these design decisions led the Stage 2 Baseline carbon footprint calculated in this LCA to be **22.5% lower** than GLA current practice, in spite of the structural challenges this building has overcome.

The Stage 2 optioneering analysis models five alternative design options demonstrating opportunities for further embodied carbon reduction.

As shown in Figure 2 and Table 1, utilising all five of these reduction options would further reduce the embodied carbon of the Proposed Development (over the Stage 2 Baseline) by **5.6%** over the building life cycle (A-C), which is equivalent to **5,436,798 kgCO_2e.**

The main recommendations for achieving the Stage 2 Potential scenario are:

Specify a concrete mix with **60% GGBS content**

↓

Explore the use of **CLT casettes** and concrete beams in place of PT slabs

↓

Specify **20% recycled content aluminium** for the façade fins

↓

Replace natural stone setts with **permeable resin-bound aggregate** in the hard landscaping

The Stage 2 Baseline results demonstrate that the current design is 22.5% less carbon intensive than the GLA benchmark defining current practice.

Results also identify the opportunity to further reduce embodied carbon emissions by 5.6% (against the Stage 2 Baseline model) across building components quantified at this stage (substructure, frame, envelope and external works).

This significant carbon reduction over the GLA current practice benchmark also demonstrates the Project Team's commitment to the aspiration of reducing embodied carbon by a total of 40% to meet the GLA Aspirational target.

During RIBA Stages 3 and 4, additional LCAs will assess all building components in detail to identify opportunities to further reduce the emissions by the remaining 17.5% (or 13.2% if the Stage 2 Potential options are incorporated) in order to meet the project's 40% carbon reduction aspiration.

Based on the current Stage 2 design, the embodied carbon footprint of the proposed development at practical completion (A1-A5) is approximately **56,546 tCO2e (635 kgCO2e/m^2 GIA)** and over the building life cycle of 60 years (A-C) is approximately **97,070 tCO2e (1,089 kgCO2e/m^2 GIA).**

	Embodied carbon over life cycle per m^2 GIA (kgCO2/m^2)	Embodied carbon over life cycle (kgCO2)
GLA Current Practice benchmark	1,400	124,741,400
British Library Stage 2 Baseline	1,089	97,069,731
Savings	**311**	**27,671,669**

By comparison to the GLA Current Practice benchmarks, the Stage 2 Baseline demonstrates a saving of approximately **27,671 tCO2e** over the building life cycle (A-C).

This tonnage of carbon equates to the following savings:

5,500

approx. return flights from London to Sydney

157,200

approx. planted trees to offset carbon

1 Introduction

1.1 Background

This document has been prepared on behalf of the British Library and SMBL Developments Ltd (Stanhope PLC and Mitsui Fudosan) as the 'Applicants' to support the applications for planning permission and listed building consent at the land to the north of the British Library ('the Site').

The Proposed Development would involve extending the northern aspect of the existing British Library to provide library accommodation; commercial space designed to cater for knowledge quarter uses (including life sciences, cultural, scientific and heritage collections and data sciences); retail space; and the Crossrail 2 works at basement level (excluding the eastern shaft) and commercial development.

The proposal is modelled to a Gross Internal Area (GIA) of 89,101 m^2 (Alinea area schedule, 23-08-21) and a design life of 60 years.

Figure 3 Illustrative view of the Proposed Development from Ossulston Street

1.2 Aim and objectives

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

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 life cycle (60 years, modules A-C)
- Identify the key building elements with the highest embodied carbon (kgCO_2e)
- Investigate a range of interventions to determine options for carbon emission reduction

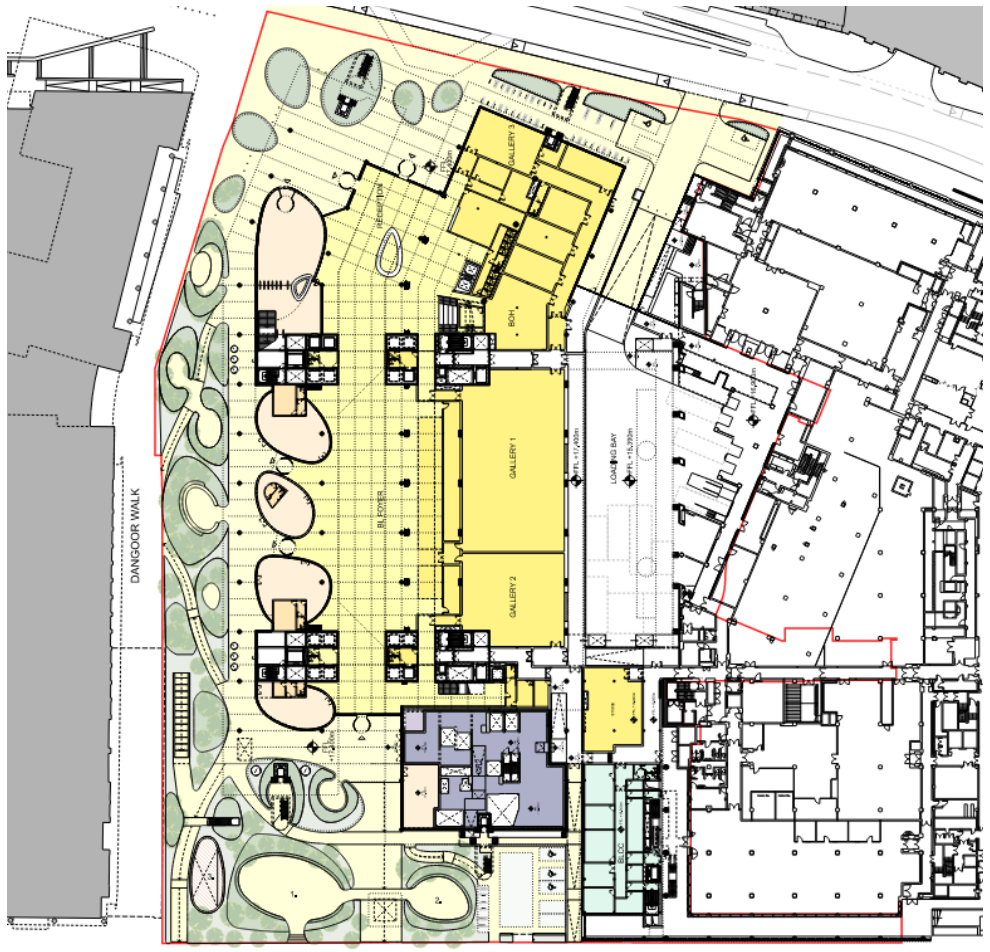


Figure 4 Proposed Lower Ground floor plan (RSHP, 24-09-2021)

1.3 Methodology

This assessment was carried out using OneClick LCA which is an IMPACT (Integrated Material Profile and Costing Tool) compliant software programme.

The study is reported according to the following scopes:

1. Emissions at practical completion (modules A1-A5)
2. Over building life cycle (modules A-C, 60 years)

The Proposed Development has been modelled at Stage 2, with the core structure as follows:

- Substructure: Raft foundation with secant perimeter piling
- Transfer level frame: Concrete primary beams and columns, glulam secondary trusses
- Upper Floors: Concrete columns and beams, timber/concrete hybrid floor slabs
- Unitised façade system: Closed cavity façade (CCF) modules, double-glazed units, brickwork

The Stage 2 Baseline emissions were calculated using Stage 2 cost plan quantities provided by Alinea on 21-06-21. Alinea were able to quantify materials in the following layers:

- Substructure
- Superstructure frame
- Superstructure envelope

These quantities were supplemented by the following:

- Façade: CCF (closed cavity façade) module build-ups provided by Arup Facades
- Substructure: Secant piling volumes provided by Arup Structures
- External works: Hard landscaping areas provided by landscape architects, DSDHA

The baseline results use material specifications provided by the design team. Where these were unavailable, default specification values provided by the RICS Professional Statement have been used. These default values define “average industry standard practice”.

Detailed information for the remaining elements including internal walls/partitions, doors, finishes, FF&E and building services were not available at Stage 2, therefore GLA benchmark values have been used to estimate their embodied carbon contribution. Wherever GLA benchmarks have been used in tables and graphs, it has been clearly noted.

It is therefore anticipated that an increase in embodied carbon could take place from Stage 2 to Stages 3+ once the missing elements are quantifiable in greater detail.

2 Results

2.1 Whole life carbon (embodied and operational)

The estimated whole life carbon emissions of the Proposed Development are summarised in Table 2. The whole life carbon emissions account for the embodied carbon and also the operational carbon, over the building's 60-year lifespan.

The results show that the Proposed Development accounts for a whole life carbon figure of approximately **195,140 tCO2e (2,190 kgCO_2e/m^2 GIA)** over the building life cycle of 60 years (A-C). Rows shaded in grey are building elements that could not be quantified at Stage 2, so use GLA benchmark values.

The operational carbon data has been provided by Arup and is detailed within the Energy Statement for the Proposed Development. The data is based on the UK Building Regulation Part L analysis Arup have undertaken of the current Stage 2 design.

The estimated operational carbon data is divided into 'regulated' and 'unregulated' sources. Regulated energy is building energy consumption that is inherent to the building design (i.e. space heating and cooling, hot water, ventilation, and lighting), whereas unregulated energy is that resulting from systems/processes that are not controlled by the design team (i.e. IT equipment, kitchen appliances, and laptops).

Table 2 Whole life carbon emissions of the Stage 2 Baseline in accordance with RICS methodology and EN 15978

	A1-A3 Product Stage	A4-A5 Transportation to site & site operations	B3-B5 Repair & Replacement	C1-C4 End of Life stage	TOTAL (kgCO_2e)
Substructure	6,515,801	785,933	0	380,963	7,682,697
Frame	15,579,534	1,432,155	590,661	756,436	18,358,786
Envelope	8,023,752	517,430	7,868,122	121,003	16,530,307
Partitions					6,682,575
Internal finishes					17,374,695
FF&E					5,346,060
Building services					24,948,280
External works	64,484	14,651	64,484	2,713	146,331
				Total Embodied Carbon	**97,069,731**
B6 Regulated					37,296,000
B6 Unregulated					60,774,000
				Total Operational Carbon	**98,070,000**
Whole life carbon: 195,139,731 kgCO_2e					

Results accounting for grid decarbonisation

The Energy Strategy produced by Arup comprises a number of passive and low energy design measures that have optimised the operational performance of the Proposed Development, which is reflected in the operational carbon figures. These measures are as follows:

- High performance glazing
- Improved building fabric thermal insulation
- Low building air leakage rate
- Low energy lighting
- Efficient central heating and cooling systems

Beyond this, the whole life carbon emissions of the Proposed Development have been modelled to account for UK grid decarbonisation forecasts.

Following RICS guidance, FES 2021 compliant adjustment coefficients have been applied to the embodied carbon assessment to calculate the future impact of the decarbonisation of the UK electricity grid. Where GLA benchmark values have been used, a decarbonisation assumption has been made in line with the modelled elements which showed that applying decarbonisation reduces the embodied carbon by an average of 11.46%.

Adjustment coefficients calculated from the FES 2021 'slow progression' scenario for a 60-year lifespan have also been applied to the operational carbon figures provided in the Energy Statement.

Table 3 Whole life carbon emissions of the Stage 2 Baseline in accordance with RICS methodology and EN 15978 accounting for FES 2021 'slow progression' grid decarbonisation

	A1-A3 Product Stage	A4-A5 Transportation to site & site operations	B3-B5 Repair & Replacement	C1-C4 End of Life stage	TOTAL (kgCO_2e)
Substructure	6,515,801	785,933		380,963	7,682,697
Frame	15,579,534	1,432,155	522,032	756,436	18,290,156
Envelope	8,023,752	517,430	6,948,934	121,003	15,611,119
Partitions					5,923,434
Internal finishes					15,400,930
FF&E					4,738,748
Building services					22,114,155
External works	64,484	14,651	56,950	2,713	138,798
				Total Embodied Carbon	**89,900,037**
B6 Regulated					8,329,005
B6 Unregulated					13,565,605
				Total Operational Carbon	**21,894,610**
Whole life carbon (with decarbonisation): 111,794,647 kgCO_2e					

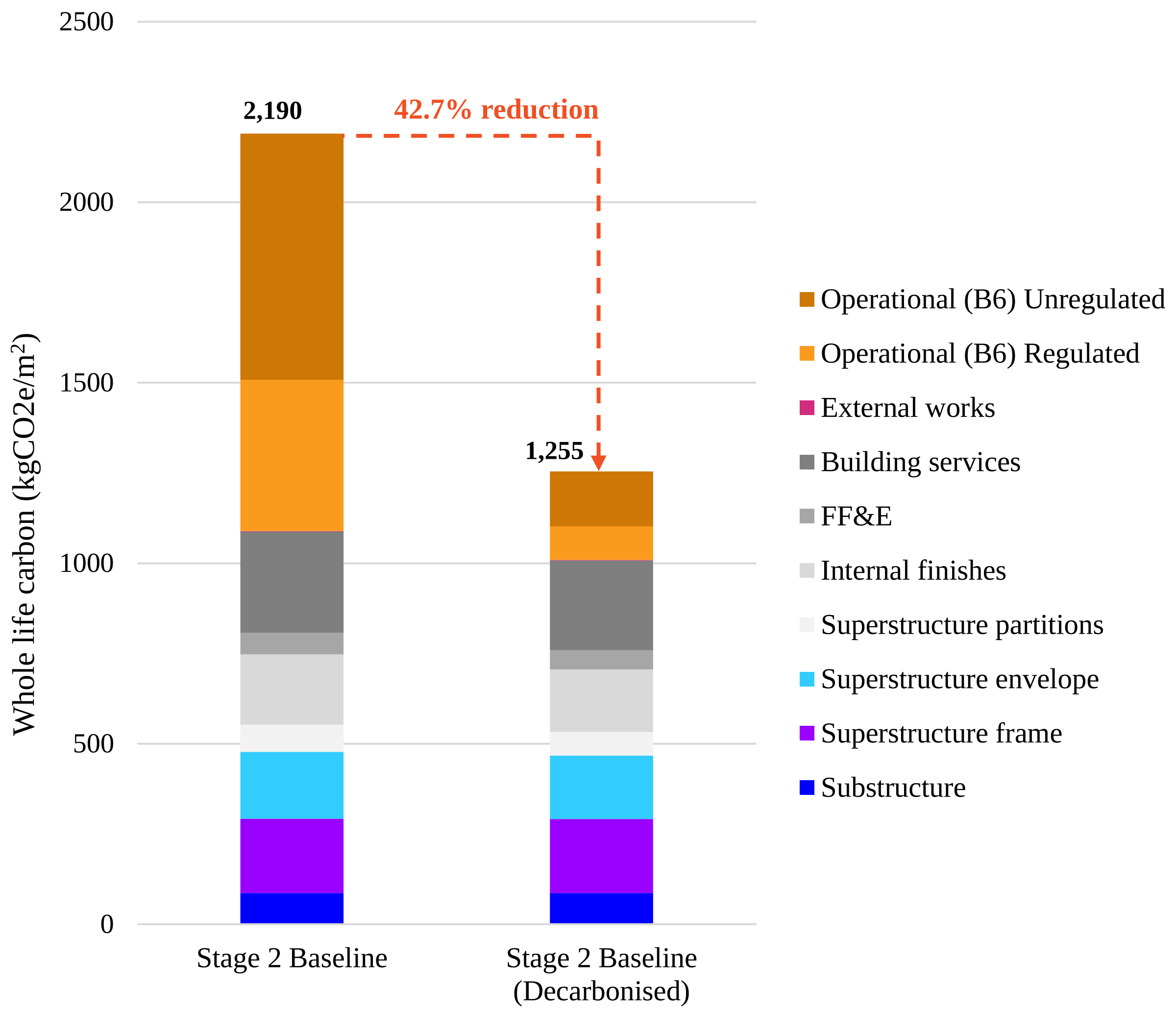


Figure 5 Whole life carbon emissions of the Stage 2 Baseline, with and without decarbonisation

Comparison of the whole life carbon emissions of the Stage 2 baseline both with and without UK grid decarbonisation are shown in Figure 5. When the decarbonisation scenario is applied, the whole life carbon emissions of the Proposed Development are shown to reduce by **42.7%** over the building life cycle (A-C), which is equivalent to **47,208,395 $kgCO_2e$.** This carbon reduction is primarily seen in the (B6) operational carbon figures (both regulated and unregulated).

2.2 Embodied carbon assessment

The estimated embodied carbon emissions of the Proposed Development at Stage 2 are summarised in Table 4. These are excluding operational carbon.

The assessment estimates that Stage 2 embodied carbon footprint of the proposed development at practical completion (A1-A5) is approximately **56,546 tCO2e (635 kgCO2e/m^2 GIA).**

The Stage 2 embodied carbon footprint of the Proposed Development over the building life cycle of 60 years (A-C) is approximately **97,070 tCO2e (1,089 kgCO2e/m^2 GIA).**

Table 4 Stage 2 Baseline embodied carbon emissions to practical completion (A1-A5) and over life cycle (A-C) per building element

Building Element	Results at practical completion (A1-A5)		Results over building life cycle (A-C)	
	$kgCO_2e$	$kgCO_2e/m^2$ GIA	$kgCO_2e$	$kgCO_2e/m^2$ GIA
Substructure	7,301,734	82	7,682,697	86
Superstructure frame	17,011,689	191	18,358,786	206
Superstructure envelope	8,541,182	96	16,530,307	186
Superstructure partitions	4,009,545	45	6,682,575	75
Internal finishes	6,682,575	75	17,374,695	195
FF&E	1,782,020	20	5,346,060	60
Building services	11,137,625	125	24,948,280	280
External works	79,135	1	146,331	2
TOTAL	**56,545,505**	**635**	**97,069,731**	**1,089**

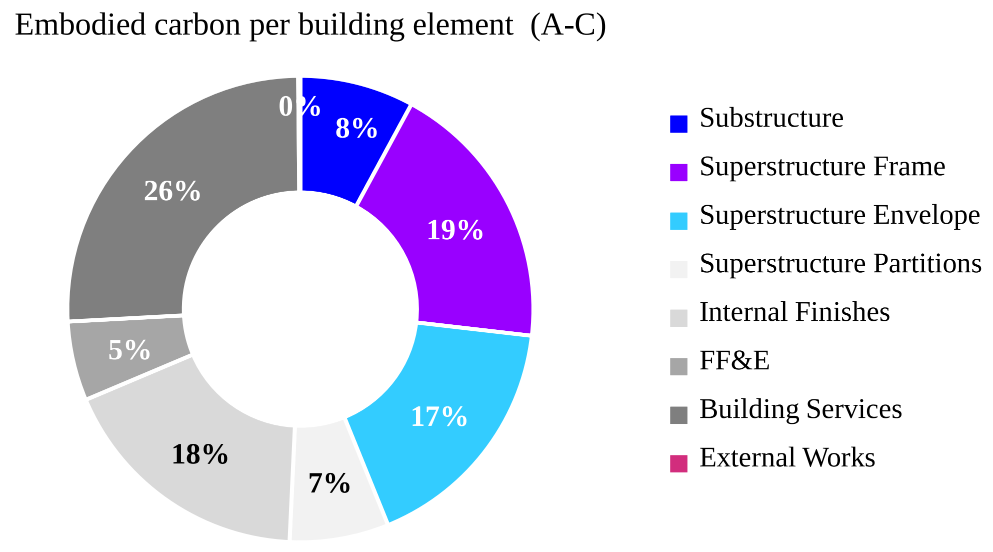


Figure 6 Breakdown of embodied carbon over life cycle per building element (A-C)

The pie chart in Figure 6 presents the embodied carbon of the Proposed Development over the building life cycle (A-C) broken down into building elements. Elements shaded in grey are not sufficiently detailed at planning stage and have therefore not been measured and quantified in the cost plan. GLA benchmark values have been used to complete the carbon footprint calculation of the building. Additional LCAs at Stages 3 and 4 will quantify and optimise the carbon emissions for these elements. Qualitative recommendations to inform early low carbon decisions for these components are included in Section 5 of this report.

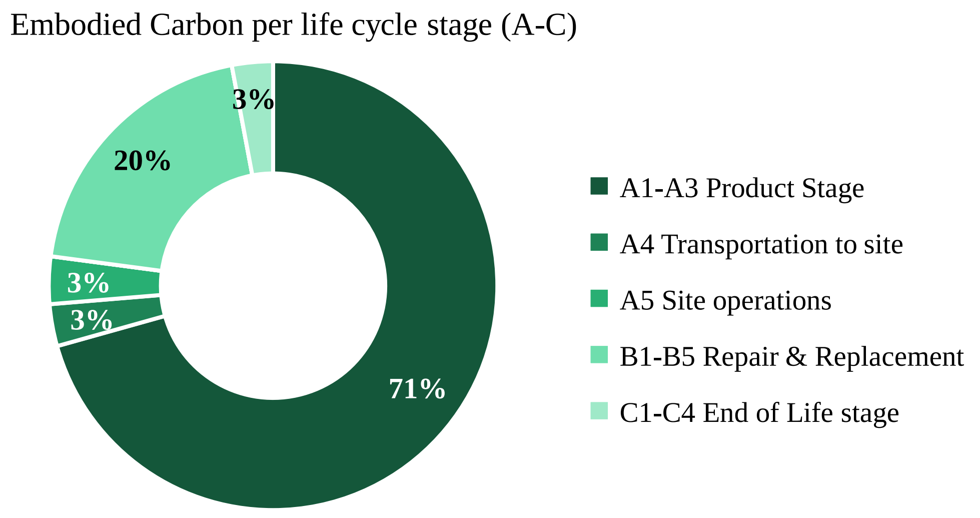


Figure 7 Breakdown of embodied carbon over life cycle per life cycle stage (A-C)

The pie chart in Figure 7 illustrates the share of embodied carbon over life cycle (A-C) for the Proposed Development per life cycle stage.

Results show that 71% of the embodied carbon emissions are attributed to the product and transportation stages (modules A1-A3). These modules focus on the extraction, processing and manufacturing of the materials (‘cradle to gate’) and therefore emphasises that the initial selection of materials is crucial in reducing the carbon emissions of the development.

Transport of equipment and materials (module A4) has been calculated in accordance with the RICS default figures because at this stage it is not possible to determine the locations, distances and means of transport for all construction materials and equipment. Consequently, the emissions which derive from stage A4 are indicative and may be reconsidered during construction.

2.3 High impact construction materials

Table 5 provides a summary of the ten key construction materials that are responsible for the greatest carbon emissions of the Proposed Development at practical completion.

The key drivers of the carbon emissions shown may be sheer quantity of material and/or carbon intensity (high impact materials).

Table 5 Construction materials with the highest embodied carbon at product stage (tCO_2e)

Material Category *NB: (Only substructure, frame, envelope and external works have been modelled)*	**Cradle to gate impacts (modules A1-A3)**	
	tCO_2e	**% of total**
Ready-mix concrete	10,293	34.10%
Reinforcement steel	4,865	16.10%
Aluminium profile	4,787	15.90%
Structural hollow steel sections	3,307	11.00%
Carbon steel reinforcing bar	2,292	7.60%
Aluminium frame windows	1,223	4.10%
Double glazing	680	2.30%
Aluminium interior blinds	596	2.00%
Float glass	412	1.40%
Concrete paving	245	0.80%
TOTAL	**28,700**	**95.30%**

2.4 Benchmark comparison

Figure 8 compares the Stage 2 Baseline design with the following benchmarks:

- London Energy Transformation Initiative (LETI): Defines current practice benchmarks and targets for 2020 and 2030 (A1-A5 only)
- The Royal Institute of British Architects 2030 Climate Challenge (RIBA): Defines benchmarks and targets for buildings to aim to meet net zero over life cycle (A-C)
- Greater London Authority (GLA): Whole-Life Carbon Guidance developed within the London Plan defines benchmarks and aspirational targets for buildings (A1-A5 and A-C).

In the graphs, the grey areas represent data gaps in the Stage 2 cost plan. In these cases, GLA office benchmark values have been used. It is important to note that while the GLA office benchmarks have been used, the Proposed Development incorporates lab-enabled office space. This requires stricter levels of specification in areas such as finishes and MEP specification, which is likely to result in an increase in embodied carbon impacts over a typical office fit out.

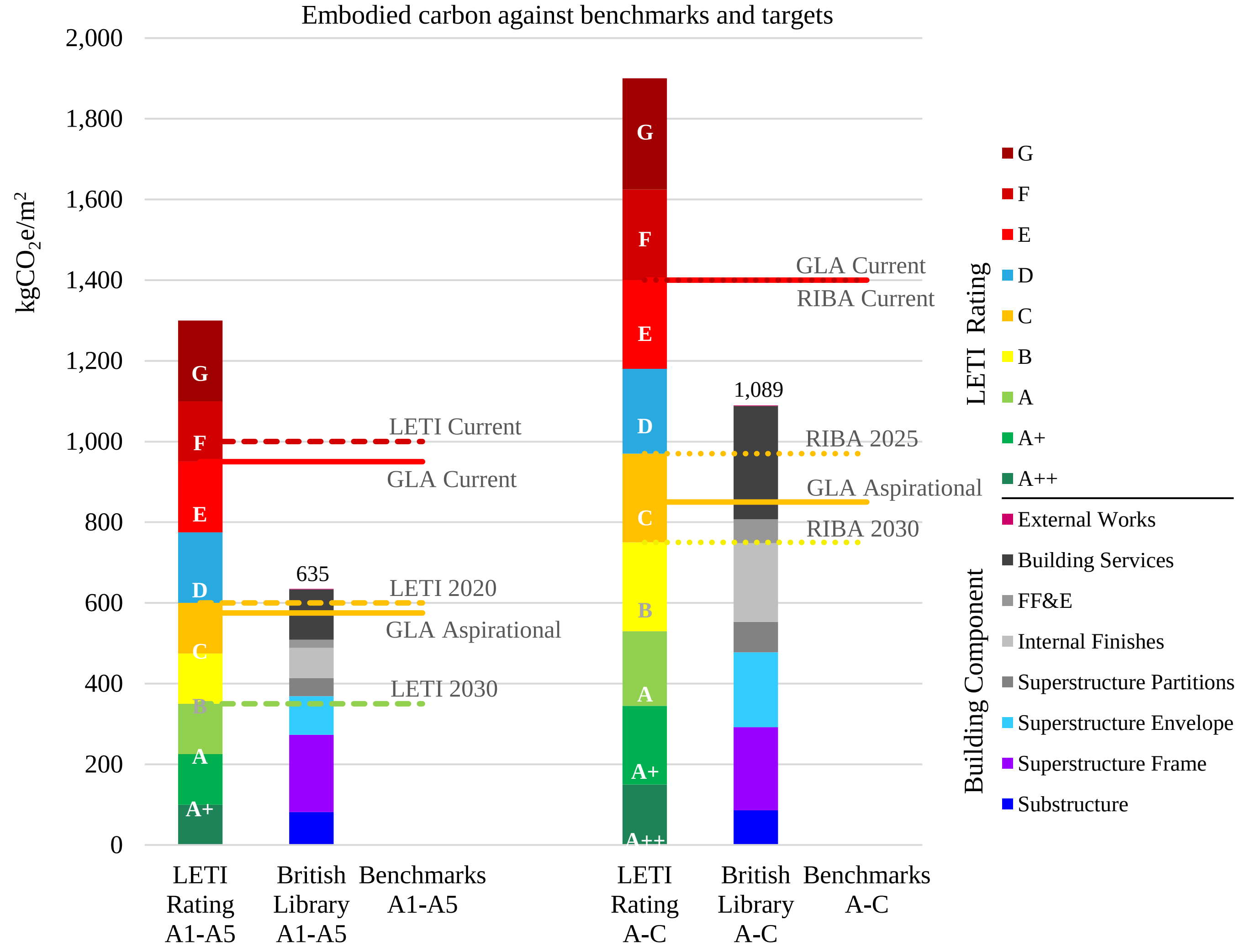


Figure 8 Baseline emissions compared to GLA, LETI and RIBA benchmarks, at practical completion (A1-A5) and over the building life cycle (A-C).

The benchmarks defined by the GLA's WLCA guidance provide a reference for the embodied carbon impact of Current Practice design, as well as an Aspirational Target (best current practice). This is defined as a 40% carbon reduction from current practice.

LETI has defined similar targets (A1-A5) for best practice embodied carbon performance at design level. The LETI target for buildings designed today (LETI 2020) aligns with the GLA Aspirational target (A1-A5).

RIBA targets define the same good practice over the building life cycle (A-C) but consider the targets to be applied to the year of completion (up to 2030).

Aligning the embodied carbon impact of the British Library Extension with the GLA's Aspirational Targets, LETI targets for 2020 and RIBA targets for 2025-2030 ensures best practice in embodied carbon performance within the current market and technical availability.

Figure 9 compares the Stage 2 Baseline design with GLA benchmark and aspirational targets at practical completion (A1-A5) and over whole life cycle (A-C), broken down into building elements. This is useful to highlight the building elements that meet the aspirational target for example the Substructure, and those that are further away from the target, for example the Superstructure Envelope. This should guide the design team in future stages to focus efforts on carbon reduction in the façade design, for example through an extended service life.

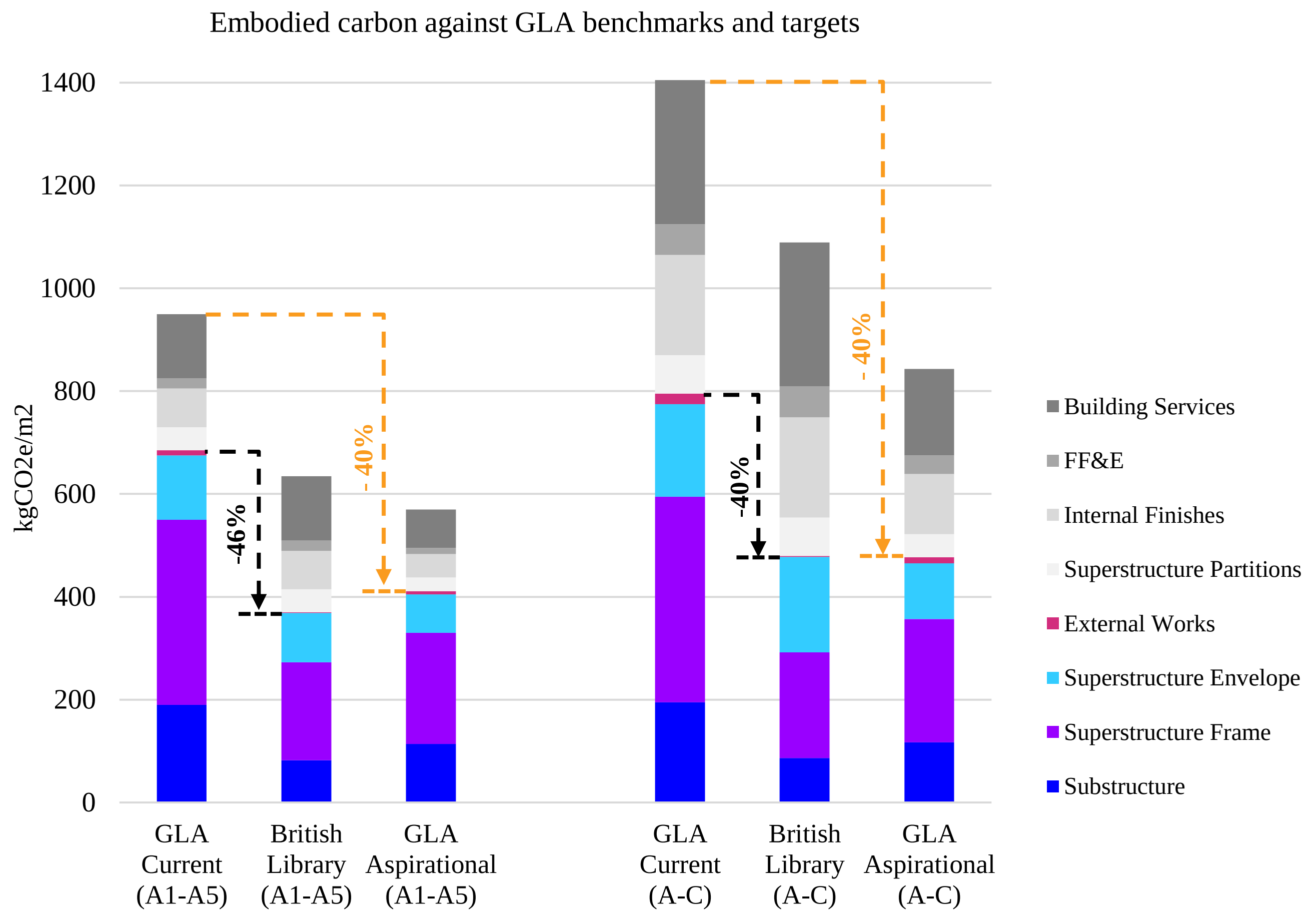


Figure 9 Baseline emissions compared to GLA benchmarks and aspirational targets, at practical completion (A1-A5) and over the building life cycle (A-C).

3 BREEAM Mat 01 Results

The Proposed Development is targeting credits under BREEAM Mat 01.

The BREEAM Materials (Mat 01) credit aims to reduce the burden on the environment from construction products. This is achieved by recognising and encouraging measures to optimise construction product consumption efficiency, and by selecting products with a low environmental impact (including embodied carbon), over the life cycle of the building.

It is important to note that work was undertaken to maximise the efficiency of the structure by Arup structural engineers at RIBA Stage 1, the outcome of which fed into the current Stage 2 Baseline design. This optimisation is therefore not captured within the BREEAM Mat 01 assessment. The British Library extension superstructure and substructure are both low embodied carbon by design and are therefore both substantially better than business as usual.

3.1 Baseline superstructure option

The first of the points available for Mat 01 is awarded based on the environmental impact of the building compared with the BREEAM LCA benchmark. The baseline option for the RIBA Stage 2 design is:

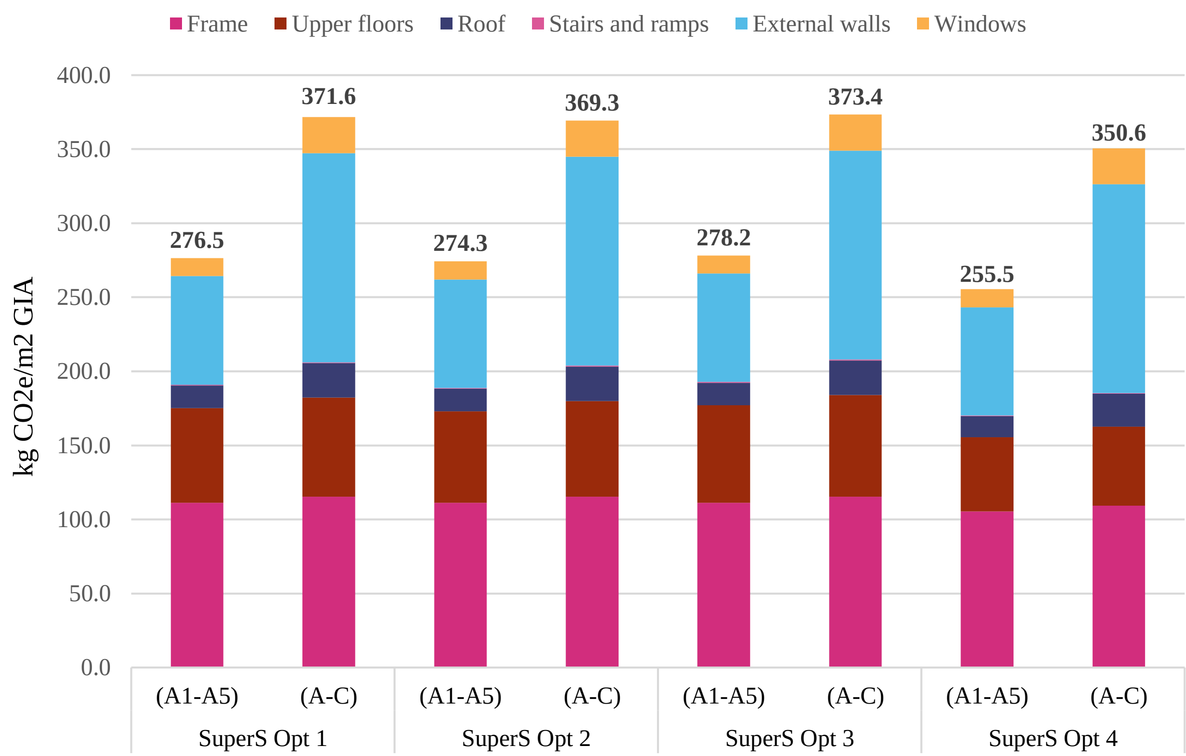
- Mat01_CD_SuperS_B

Compared with the BREEAM LCA benchmark, the Stage 2 baseline achieves 4.06 no. ecopoints/m^2 NIA, which equates to 69.3% worse than the benchmark. The project is performing worse than the BREEAM benchmark, therefore it does not achieve the point available for this element of the Mat 01 credit.

3.2 Superstructure options appraisal

Different design options were considered at RIBA Stage 2 to explore reduction of the building's environmental impact. For the BREEAM options appraisal, 4no. significantly different design options for the superstructure have been considered and are presented in the table below. The orange cross denotes an option that has not been chosen within the baseline design but has been identified as an opportunity for further exploration at the next stage.

Superstructure Option Ref	Description	Chosen Option
Option 1 (Baseline) Mat01_CD_SuperS_Opt1	40% GGBS content in concrete mix CLT Infills (less PT slabs)	✓
Option 2 Mat01_CD_SuperS_Opt2	CLT Cassettes and concrete beams (less PT slabs)	✗
Option 3 Mat01_CD_SuperS_Opt3	PT slabs (no CLT)	✗
Option 4 Mat01_CD_SuperS_Opt4	60% GGBS content in concrete mix	✗



Percentage change from baseline Opt 1		SuperS Opt 2 (A1-A5)	SuperS Opt 2 (A-C)	SuperS Opt 3 (A1-A5)	SuperS Opt 3 (A-C)	SuperS Opt 4 (A1-A5)	SuperS Opt 4 (A-C)
	(A1-A5)	- 0.80 %		+ 0.63 %		- 7.60 %	
	(A-C)		- 0.62 %		+ 0.47 %		- 5.65 %

Figure 10 Summary of superstructure results A1-A5 (EC-PC) and A-C (EC-LC)

Figure 10 compares all 4 superstructure options. Each option reports embodied carbon stages to practical completion (A1-A5) as well as over the life cycle (A-C). Each column is split according to the different categories' contributions. The figure does not include construction site operations.

Superstructure Option 1 is the baseline model and utilises CLT infills and retains the baseline 40% GGBS content in the concrete mix. This has an embodied carbon over the building life cycle (A-C) of 371.6 kgCO2e/m^2. Superstructure Option 3 which incorporates no CLT infills has a 0.47% higher embodied carbon over the building life cycle (A-C), performing the worst of the modelled options.

Superstructure Option 4 with the highest GGBS content in the concrete mix (60% GGBS) has the lowest embodied carbon over the building life cycle (A-C). This is 5.65% lower than the baseline Option 1, demonstrating the positive impact of increased GGBS content. In RIBA Stage 3 the structural team should explore the capacity of the structure to adopt higher GGBS content, including considerations towards program, and potential cost implications.

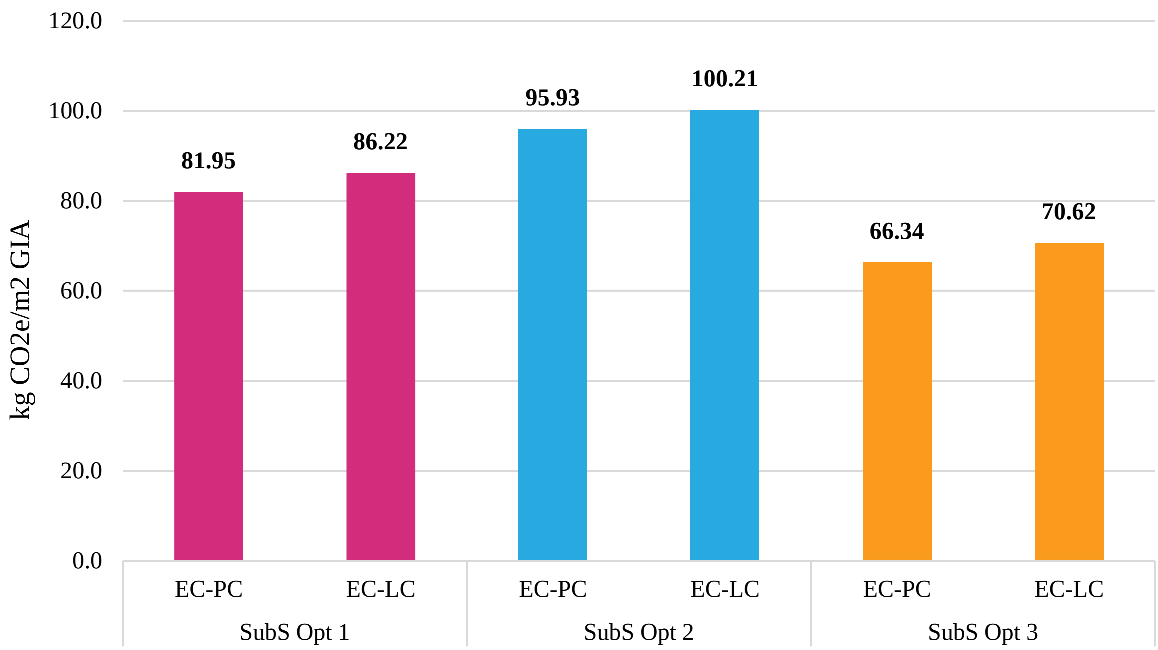
Superstructure Option 2 incorporates CLT cassettes into the frame design and has a 0.62% reduction in embodied carbon over the building life cycle (A-C) compared to baseline Option 1. Given the lack of detailed quantities available at this stage, it is estimated that these values give a conservative insight into the potential embodied carbon reduction from the use of CLT cassettes. Further investigations in later design stages (with the incorporation of the carbon sequestration potential of timber) are recommended to explore the full potential of this design option.

3.3 Substructure options appraisal

For the BREEAM options appraisal, 3no. significantly different design options have been considered at RIBA Stage 2 to explore the reduction of the environmental impact of the substructure. All substructure options are modelled on the current design of a raft foundation with secant piling.

All the substructure design options are presented in the table below. The orange cross denotes an option that has not been chosen within the baseline design, but has been identified as an opportunity for further exploration at the next design stage.

Substructure Option Ref	Description	Chosen Option
Option 1 (Baseline) Mat01_CD_SubS_HL_Opt1	40% GGBS content in concrete mix	✓
Option 2 Mat01_CD_SubS_HL_Opt3	20% GGBS content in concrete mix	✗
Option 3 Mat01_CD_SubS_HL_Opt4	60% GGBS content in concrete mix	✗



Percentage change from baseline Opt 1					
	(A1-A5)	+ 17.06 %		- 19.05 %	
	(A-C)		+ 16.21 %		- 18.10 %

Figure 11 Summary of substructure results A1-A5 (EC-PC) and A-C (EC-LC)

Figure 11 shows that there is a notable reduction in embodied carbon between the substructure options. This figure does not include construction site operations. The current baseline Option 1 uses 40% GGBS content in the concrete mix. Option 3 uses a higher content of 60% GGBS in the concrete mix and demonstrates an 18.10% reduction in embodied carbon over the building life cycle (A-C) compared to baseline Option 1. This is a positive result because the GGBS content can be optimised in later design stages during early procurement exercises. A higher content will however need to be discussed with both the design team and the client, because it affects curing time, which in turn affects the project programme.

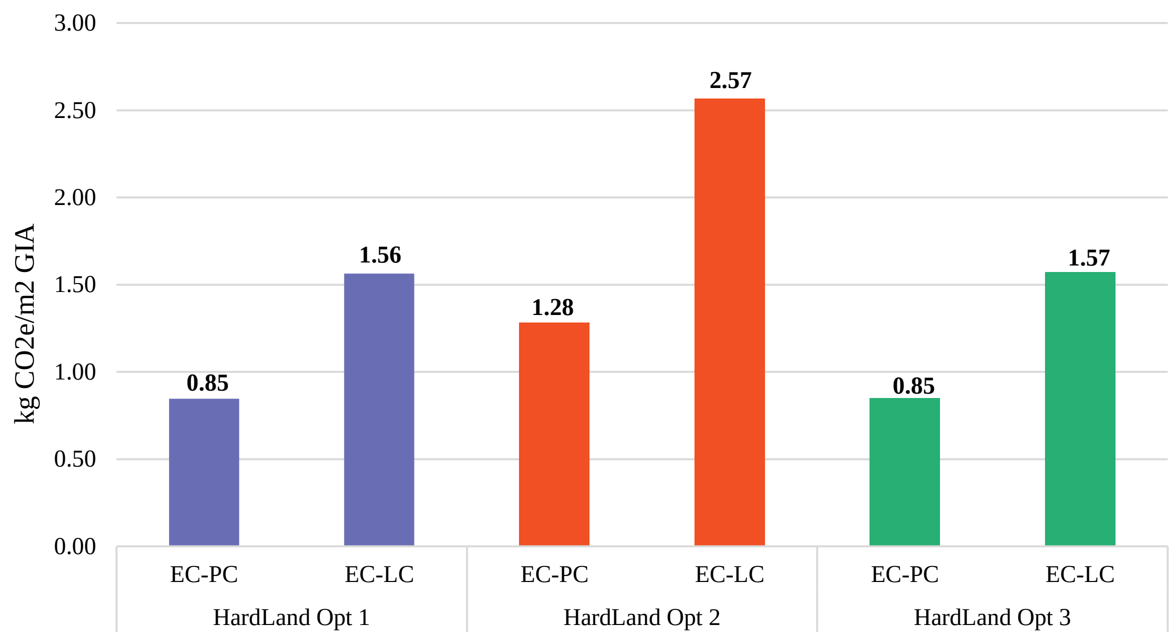
3.4 Hard landscaping options appraisal

For the BREEAM options appraisal, 3no. significantly different design options have been considered at RIBA Stage 2 to explore the reduction of the environmental impact of the hard landscaping. These were provided by landscape architects DSDHA on 04/08/2021. This study does not include construction site operations.

All the hard landscaping design options are presented in the table below:

Hard Landscaping Option Ref	Description	Chosen Option
Option 1 (Baseline) Mat01_CD_SubS_HL_Opt2	381 m^2 Permeable resin-bound aggregate 128 m^2 Concrete grass-crete 320 m^2 Parking asphalt 2986 m^2 Natural stone setts *Total hard landscaping = 3815 m^2*	✓
Option Mat01_CD_SubS_HL_Opt5	509 m^2 Permeable resin-bound aggregate 3306 m^2 Brick paving *Total hard landscaping = 3815 m^2*	✗
Option Mat01_CD_SubS_HL_Opt6	381 m^2 Permeable resin-bound aggregate 128 m^2 Concrete grass-crete 1567 m^2 Concrete flags 1739 m^2 Concrete block paving units *Total hard landscaping = 3815 m^2*	✗

Figure 12 shows that Option 1 (the baseline option) marginally has the lowest embodied carbon. Option 1 and Option 3 have similar embodied carbon impacts. However, it also shows that hard landscaping Option 2 has a significantly higher embodied carbon value. This is due to the use of brick paving which is more carbon intensive than concrete flags.



Percentage change from baseline Opt 1	(A1-A5)	+ 51.54 %		+ 0.40 %	
	(A-C)		+ 64.14 %		+ 0.65 %

Figure 12 Summary of hard landscaping results A1-A5 (EC-PC) and A-C (EC-LC)

3.5 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. The OneClick LCA 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 ‘new-build’ scheme are summarised in Table 6.

Table 6 BREEAM Mat 01 credits achieved at RIBA Stage 2

	Benchmark comparison	Options appraisal		Credits Achieved
	Superstructure	Superstructure	Substructure & Hard Landscaping	
Concept Design	0	2.67	1	3
Technical Design	To be updated at Stage 4			0
TOTAL	-	-	-	3

The number of BREEAM Mat 01 credits achieved at RIBA Stage 2 is 2no. credits for the appraisal of 4no. superstructure design options and 1 further credit for the appraisal of 3no. substructure and 3no. hard landscaping design options. Further LCA modelling of the superstructure is required at RIBA Stage 4 to achieve further credits.

4 Opportunities for embodied carbon reduction

Following the BREEAM Mat 01 options appraisal, further optioneering has taken place to identify valuable actions to reduce the embodied carbon at this design stage. These are Options A, B, C, D and E. Where BREEAM Mat 01 options were shown to offer significant savings, they have been incorporated into the Options. This has occurred as follows:

- BREEAM Substructure Option 3 aligns with proposed Option A
- BREEAM Superstructure Option 2 aligns with proposed Option B
- BREEAM Superstructure Option 4 aligns with proposed Option C

Proposed Options D and E offer new reduction opportunities that go beyond those modelled within the BREEAM Mat 01 assessment.

A summary of recommendations to reduce the embodied carbon footprint of the proposed scheme are presented in Table 7. The Stage 2 Baseline assessment uses material specifications provided by the design team. Where material specifications were unavailable, default values have been used according to the RICS Professional Statement, which define "average industry standard practice".

Table 7 Alternative designs modelled and resulting savings in embodied carbon at practical completion (A1-A5) and over life cycle (A-C, 60 years)

			Stage 2 Baseline	Reduction Options	Savings (A1-A5)		Savings (A-C)	
	Category	**Element(s)**	**Assumptions**	**Assumptions**	**$kgCO_2e$**	**%**	**$kgCO_2e$**	**%**
A	**Substructure**	Concrete elements	40% GGBS content in concrete mix	60% GGBS content in concrete mix	1,390,649	2.46%	1,390,649	1.43%
B	**Superstructure**	Upper floors	CLT infills 40% GGBS content in concrete mix	CLT cassettes + concrete beams 40% GGBS content in concrete mix	197,749	0.35%	205,492	0.21%
C	**Superstructure**	Upper floors	CLT infills 40% GGBS content in concrete mix	CLT infills 60% GGBS content in concrete mix	1,871,913	3.31%	1,866,730	1.92%
D	**Facade**	Façade	Standard aluminium fins	20% recycled content in aluminium fins	994,196	1.76%	1,918,705	1.98%
E	**Hard Landscaping**	Paving	381 m^2 Permeable resin-bound aggregate 128 m^2 Concrete grass-crete 320 m^2 Parking asphalt 2986 m^2 Natural stone setts	Replacement of all natural stone setts ($2986m^2$) with Permeable resin-bound aggregate	29,614	0.05%	55,222	0.06%
				Total Savings	**4,484,120 $kgCO_2e$**	**7.93% (A1-A5)**	**5,436,798 $kgCO_2e$**	**5.60% (A-C)**

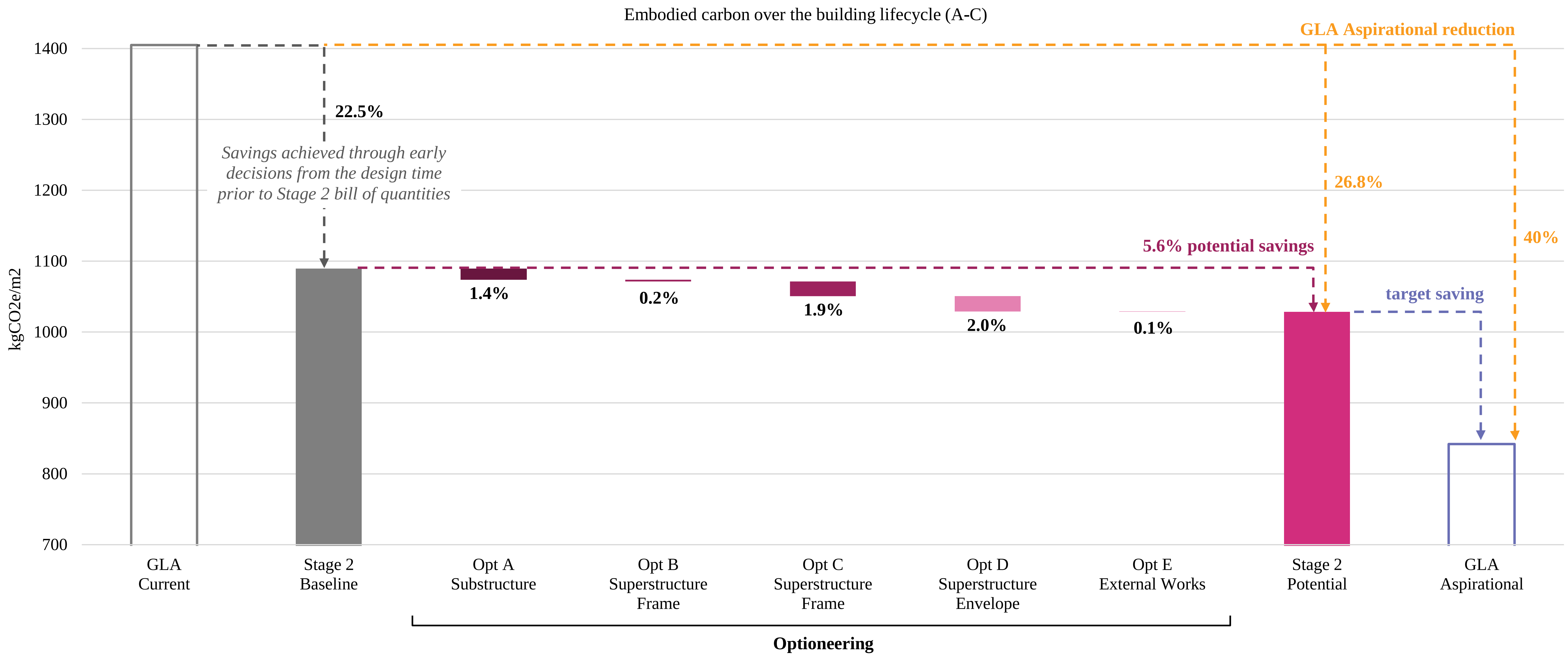


Figure 13 Waterfall graph showing the potential embodied carbon reduction from alternative design options, against GLA Current and GLA Aspirational targets over the building life cycle (A-C)

The Stage 2 optioneering analysis models five alternative design options (Opt A to Opt E) demonstrating opportunities for embodied carbon reduction. As shown in Figure 13 utilising all five of these reduction options would reduce the embodied carbon of the Proposed Development by **5.60%** over the building life cycle (A-C), which is equivalent to **5,436,798 kgCO$_2$e.**

The Stage 2 Baseline demonstrates a betterment of 22.5% embodied carbon over the building life cycle (A-C) by comparison to the GLA Current practice benchmark. This has been achieved through design optimisation from the earliest design stages prior to the Stage 2 proposal, for example in the design of the foundations and superstructure.

The Proposed Development incorporates CLT into the Stage 2 Baseline design which is not typical practice, and also uses better specification by default with all concrete constituting 40% GGBS content. The façade was also optimised through early-stage studies comparing the embodied carbon impact of aluminium, bronze and terracotta. The aluminium façade was shown to be most carbon efficient and was therefore selected for the Stage 2 Baseline design.

The main recommendations for achieving the Stage 2 Potential scenario are as follows:

Option A: The specification of a concrete mix for the substructure with 60% GGBS content would significantly reduce the embodied carbon impact of the proposal. Modelling demonstrates a saving of 1.43% which is equivalent to 1,390,649 kgCO$_2$e.

Option B: The use of CLT casettes and concrete beams in place of PT slabs for the superstructure shows potential for embodied carbon savings in later design stages. Present modelling demonstrates a saving of 0.21% which is equivalent to 205,492 kgCO$_2$e.

Given the lack of detailed quantities available at this stage, it is estimated that these values give a conservative insight into the potential embodied carbon reduction from the use of CLT cassettes. Further investigations in later design stages (with the incorporation of the carbon sequestration potential of timber) are recommended to explore the full potential of this design option.

Option C: As in the substructure, the specification of a concrete mix with 60% GGBS content for the superstructure would significantly reduce the embodied carbon impact of the proposal by comparison to a 40% GGBS content specification (as was modelled in the Stage 2 Baseline assessment). Modelling demonstrates a saving of 1.92% which is equivalent to 1,866,730 kgCO_2e.

Option D: Specifying aluminium containing 20% recycled content for the façade fins has been shown to have a positive impact in reducing the building’s embodied carbon. Modelling demonstrates a saving of 1.98% which is equivalent to 1,918,705 kgCO_2e, compared to the Stage 2 Baseline model which uses a standard aluminium with no recycled content.

Option E: Altering the hard landscaping materials selected for the design of external areas of the Proposed Development can reduce the embodied carbon. Landscape architects, DSDHA, provided quantities for 3 alternative design options as part of the BREEAM Mat01 assessment, and selected the option with the lowest embodied carbon to form the current Stage 2 Baseline design.

Within this, the permeable resin-bound aggregate has a lower embodied carbon than the natural stone setts, so Option E has been modelled with full replacement of the natural stone setts (2986m^2) with permeable resin-bound aggregate. Compared to the Stage 2 Baseline model, this change demonstrates a saving of 0.06% which is equivalent to 55,222 kgCO_2e.

5 Carbon comparative studies

The following carbon comparative studies should act as further options to develop the ‘Potential’ design scenario and to inform early decisions in the selection of materials for the building components not sufficiently defined at planning stage. We recommend targeting the frame and building services, as these areas typically make up the highest proportion of the whole building embodied carbon emissions.

5.1 Frame

Structural concrete

Concrete production is one of the most carbon intensive industries, creating up to 50% of worldwide man-made carbon dioxide emissions. Where its use cannot be avoided, for instance in the substructure, high Portland cement (PC) replacement should be targeted. Partial replacement of conventional clinker can be achieved with alternatives such ground granulated blast-furnace slag (GGBS) or pulverised fly ash (PFA). These materials are also typically cheaper than Portland cement.

The pie charts below illustrate the embodied carbon impact of the cement in concrete for the product stage only (A1 to A3). Though it forms only approximately 11% of the overall mass, it is responsible for 97% of the embodied carbon. Prioritising cement replacement options when considering how to best reduce embodied carbon is therefore sensible.

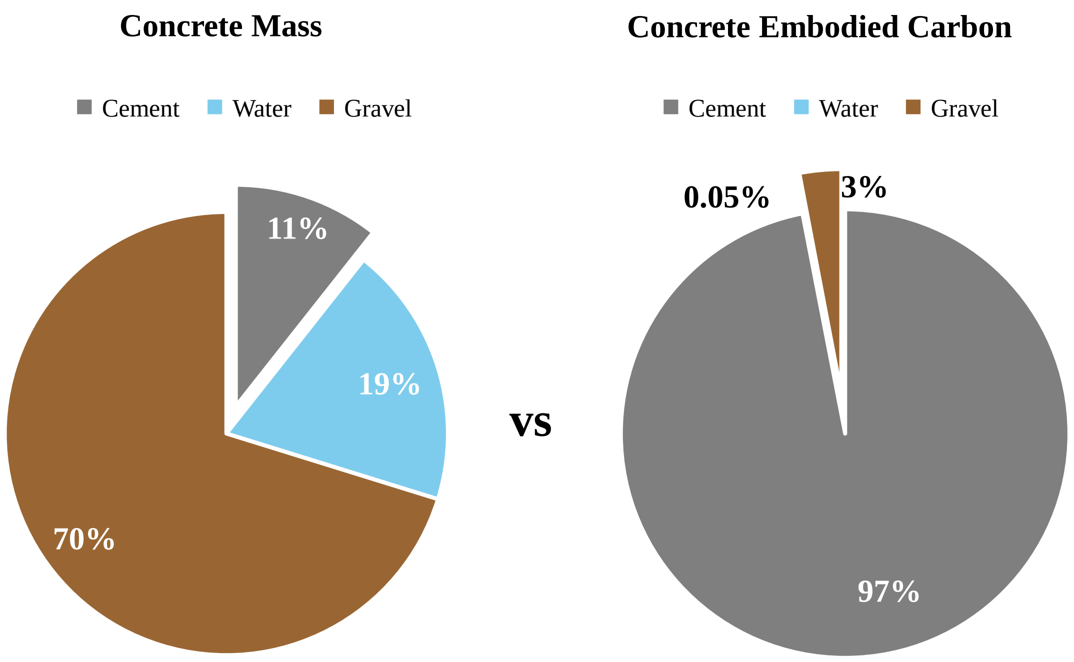


Figure 14 Concrete mass versus embodied carbon impact

An analysis was conducted to show the impact on the embodied carbon emissions of different percentages of cement replacement up to 100% (CEMfree). For this study, 50 km distance for transport to the site was assumed. However, the design team and the Contractor should consider opportunities of collaboration with suppliers closer to the British Library Extension site, where possible.

Structural steel

Structural steel provides high strength with a relatively low weight. It is 100% recyclable without degrading, enabling recycling and reuse multiple times. Secondary steel (scrap steel) holds an economic value leading to very high steel recovery rates (>90% for the construction industry according to estimations by steel associations).

Steel is produced via two main routes: the blast furnace-basic oxygen furnace (BF-BOF) route and the electric arc furnace (EAF) route. The key difference between the routes is the type of raw materials they consume. For the BF-BOF route these are predominantly iron ore, coal and recycled steel, while the EAF route produces steel using mainly recycled steel and electricity.

European manufactured structural steel sections are currently manufactured mainly via the BOF route. This process utilises approximately 20-30% of recycled steel scrap.

For this study, 300 km distance for transport to site was assumed. However, the design team and the Contractor should consider opportunities for collaboration with suppliers close to site, where applicable. UK and other European manufacturers should be considered when steel is produced via EAF route (low carbon electricity mix). HISTAR sections are a lower carbon alternative but they need to be procured from Europe (1500km distance for transport to site) and are subject to availability.

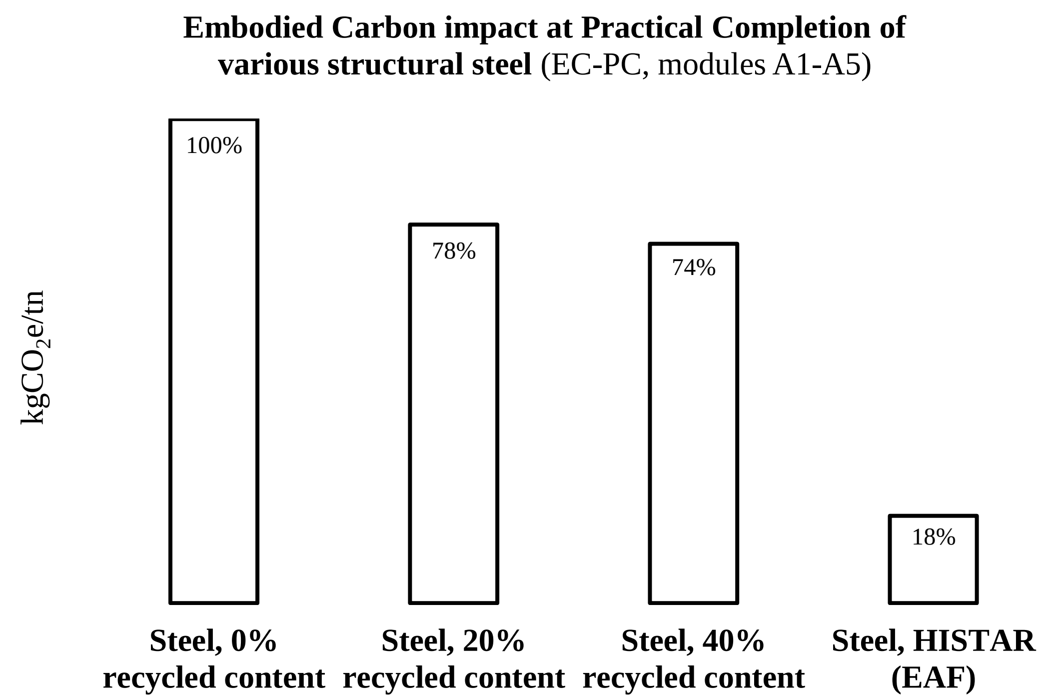


Figure 15 Embodied carbon at practical completion of various structural steel sections

5.2 Building services

In the case of building services, engineers have long been considering the operational carbon through the impacts of wider mechanical, electrical and plumbing strategies, however there is a need to also understand the embodied carbon impact of those systems so that informed choices can be made using ‘whole life’ thinking.

Design decisions are being investigated to reduce the amount of physical material required by services in the Proposed Development, which will reduce the embodied carbon. Strategies to reduce material volume as are follows:

- Low-level underfloor ventilation paired with a chilled soffit is being reviewed for areas of the building where internal loads allow, i.e. north commercial office floors. This has the benefit of removing significant amounts of ductwork on office floors and removing on-floor emitters such as FCUs. This results in a significant reduction in embodied carbon.
- Positioning equipment close to their point of use acts to minimise services distribution, and therefore the associated material required. Additionally, the grouping of similar adjacent spaces on the same mechanical and electrical systems can reduce overall distribution required.
- Reducing internal loads will reduce overall distribution sizes (e.g. pipe sizes) which provides additional materials (and therefore embodied carbon) savings.

The design team is encouraged to continually review alternative low carbon materials and track design decisions relating to them.

Ductwork

In comparing the embodied carbon impact of different ductwork options, a circular duct of 400mm dia and 1-metre length was used as the functional unit all assumed to meet the same performance standards. The three options modelled are:

- Traditional galvanised steel duct with 50mm thk Rockwool insulation
- Traditional galvanised steel duct with 50mm thk Paroc insulation
- Pre-insulated non-metal duct with 90mm thk phenolic insulation (e.g. ‘Koolduct’)

The above calculations also allow for galvanised steel fixings (suspension rings etc).

The pre-insulated ductwork (‘Koolduct’) has the lowest embodied carbon impact thanks to the omission of the galvanised steel casing which is the most carbon intensive element of typical ducts. Although this ductwork type does not always meet the air tightness and pressure resistance requirements for all office spaces and it may compromise the ventilation system's performance, the MEP Engineer is advised to investigate whether it can be used in non-office use areas like plant rooms and back-of-house. Alternatively, replacing the standard stone wool insulation with similar less carbon intensive products (such as Paroc), can provide some embodied carbon savings.

Another low carbon alternative for ductwork is corrugated cardboard (such as GatorDuct). This product was not modelled in this instance as the manufacturer could not provide its Environmental Product Declaration (EPD).

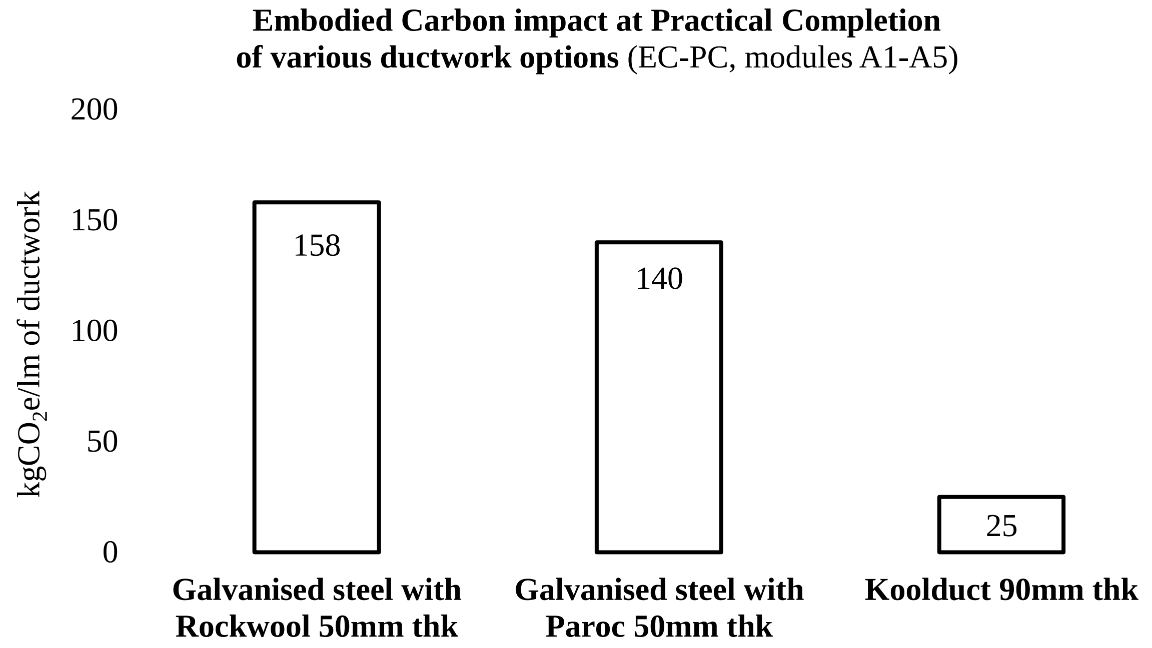


Figure 16 Embodied carbon at practical completion of various ductworks

Pipework

There are a number of factors for consideration in selection of pipework however this comparative study (summarised in Figure 17) provides and comparison of common pipework materials.

The functional unit of this study is 2” (50mm) NB pipe and 1-metre length. Corresponding wall thicknesses and weight per metre used for this study are noted in the reference for each item, below.

- Steel pipe (Schedule 40)[1] (specific steel type not specified, refer to specific dataset[2])
- Steel pipe (Schedule 80)[8] (specific steel type not specified, refer to specific dataset[9])
- Copper (Type L)[3]
- Cast iron[4]
- PVC (Schedule 40)[5]
- PVC (Schedule 80)[12]

Note that this study compares pipes of 2” diameter which may not be directly comparable due to specific performance limitations. Furthermore, the difference in embodied carbon between these materials at larger pipe diameters may be different as pipe wall thicknesses (and

[1] http://www.cooperindustries.com/content/dam/public/bline/Resources/Library/catalogs/pipe_hangers/pipe_hangers_and_supports/rd-schedule4080steelpipedata.pdf

[2] https://www.oekobaudat.de/OEKOBAU.DAT/datasetdetail/process.xhtml?uuid=8622539c-592c-45b0-9a4b-e5f8b4fea367

[3] http://www.cooperindustries.com/content/dam/public/bline/Resources/Library/catalogs/pipe_hangers/pipe_hangers_and_supports/rd-coppertubingdata.pdf

[4] http://www.cooperindustries.com/content/dam/public/bline/Resources/Library/catalogs/pipe_hangers/pipe_hangers_and_supports/rd-castironsoilpipedata.pdf

[5] http://www.cooperindustries.com/content/dam/public/bline/Resources/Library/catalogs/pipe_hangers/pipe_hangers_and_supports/rd-schedule4080pvcplasticpipedata.pdf

therefore kg/m) are expected to increase at different rates depending on specific material properties and performance requirements.

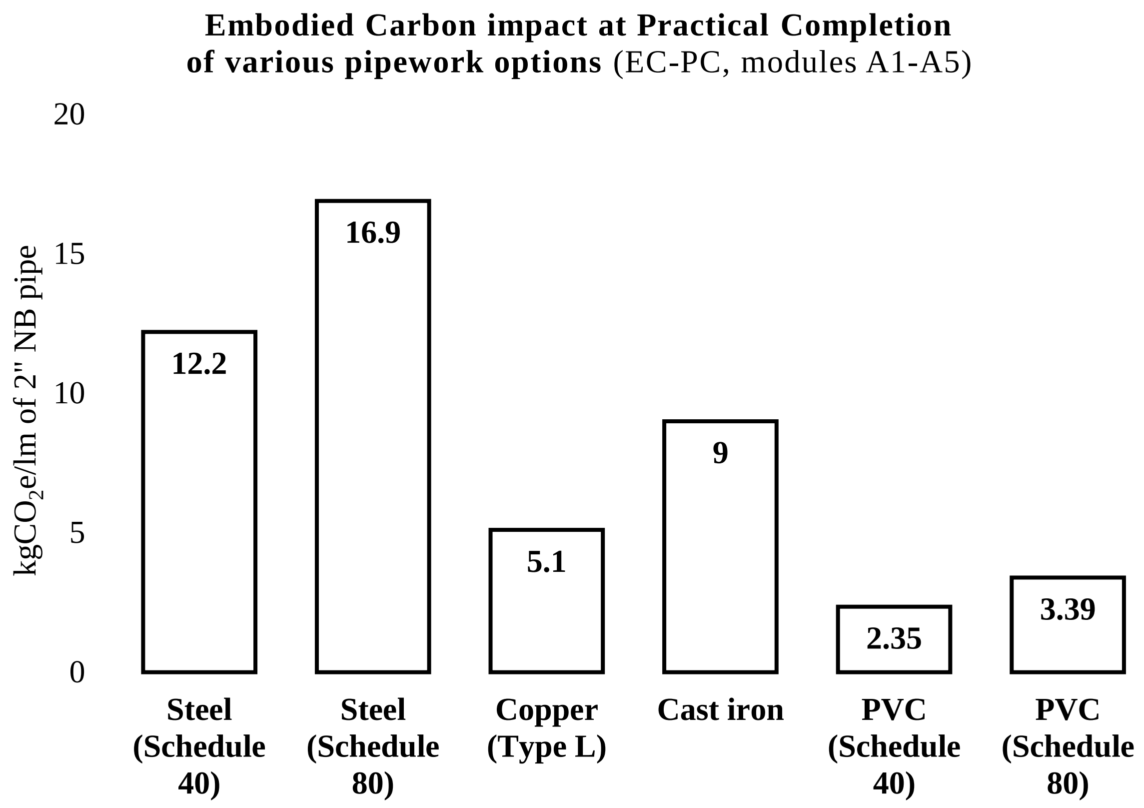


Figure 17 Embodied carbon at practical completion of various pipework materials

6 Conclusions

The following conclusions can be drawn from this study:

- The British Library development is **on track** to achieve its aspiration of **40% carbon reduction from current practice**. This aspiration has already been achieved for the building components sufficiently designed at this stage (substructure, frame, envelope and external works).
- The Stage 2 embodied carbon footprint of the proposed development at practical completion (A1-A5) is approximately **56,546 tCO2e (635 kgCO2e/m^2 GIA).**
- The Stage 2 embodied carbon footprint of the proposed development over the building life cycle of 60 years (A-C) is approximately **97,070 tCO2e (1,089 kgCO2e/m^2 GIA).**
- Alternative design options (Options A, B, C, D and E) are recommended for feasibility testing by the design team. If these options are implemented into the design, then modelling suggests that the embodied carbon footprint could drop to **91,632,933 kgCO_2e (1,028 kgCO_2e/m^2 GIA)** over the building life cycle of 60 years (A-C).
- The whole life carbon emissions of the Proposed Development are approximately **195,140 tCO2e (2,190 kgCO_2e/m^2 GIA)** over the building life cycle of 60 years (A-C). Within this figure, operational carbon accounts for **50.3%** of the total.
- It is recommended that the design team review the findings of this study and carry out feasibility testing to ensure the viability of these changes. If one, or a combination, of the alternative options investigated in this study are pursued then it is suggested that the embodied carbon is tracked stage on stage through further LCA study. The findings of this study should be evaluated with consideration of the study limitations.

Any further steps taken during RIBA Stages 2-4 and the construction stage to reduce embodied carbon should be documented for future learning through materials workshops attended by members of the project team to identify materials efficiency opportunities for the project.

The following next steps are recommended to be explored during Stages 2-4 to further reduce the embodied carbon of the British Library Extension:

1. Maximise opportunities to use reclaimed or recycled components: e.g. recycled materials from the demolished building
2. Model internal walls/partitions, doors, finishes, FF&E and building services items using detailed information, rather than GLA benchmarks as have been used in this study. Detailed information for these items would be required from the design team.

Appendix A - Methodology

A.1 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 in order 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 18 below.

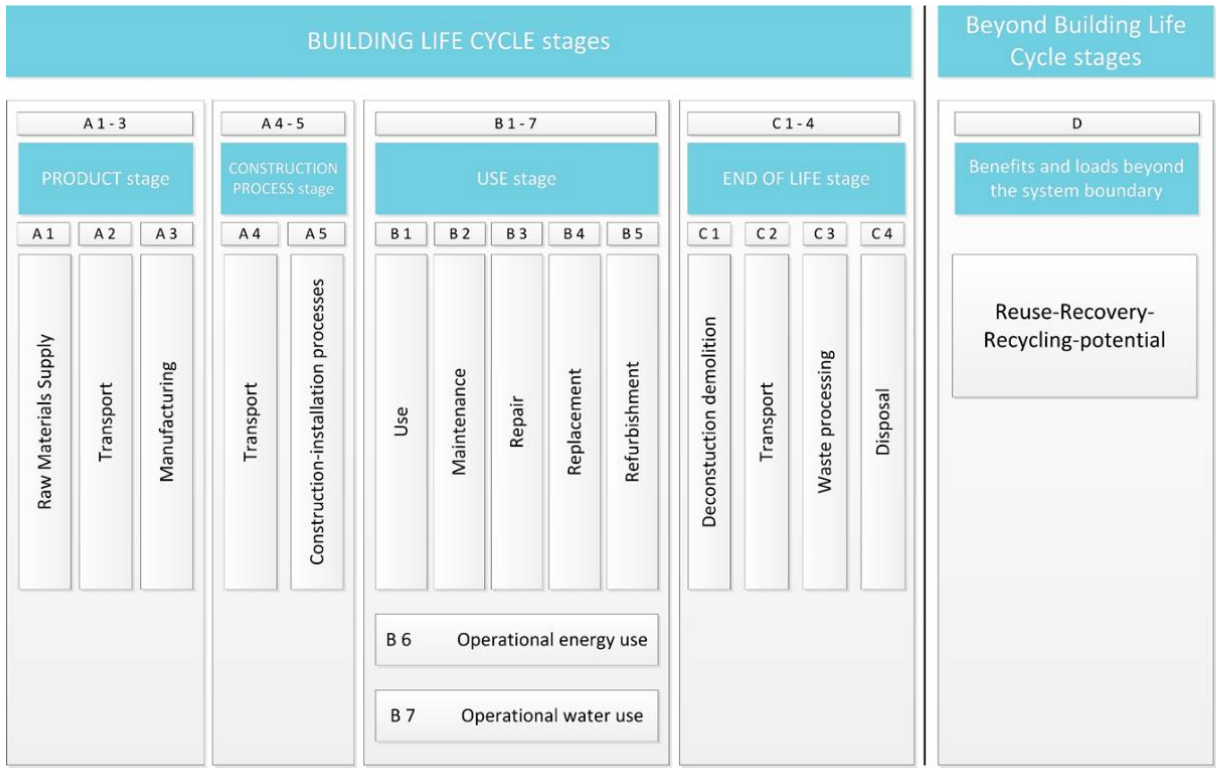


Figure 18 Building life cycle stages as defined in BS EN 15978: 2011

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.

A.2 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.

In order 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 2 (these are highlighted where applicable throughout the report)
- Transport distances (affects module A4). The fourth column in Table 8 lists the materials in this LCA that are assumed to fall within each transport category:

Table 8 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 9 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
	Ceiling finishes Substrate/Paint	20/10 respectively
FFE	Loose furniture and fittings	10

Building part	Element	Expected lifespan (years)
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

A.3 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 and quantities, are from the Stage 2 Cost Plan provided by Alinea. There are also a number of additional clarifications which came from discussions with members of the design team, such as the façade consultant and structural engineer.

A.4 Study limitations

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

- It is based on the RIBA Stage 2 information provided by the cost consultant. 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.
- Assumptions are based on industry best practice have been made when insufficient details have been provided.
- 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.
- Alternative design options have been evaluated individually and do not take account of potential resulting impacts. The alternative options are based on material quantity estimates by the design team, not a fully designed solution. The design team will need to evaluate the feasibility of the alternative design options.
- The time-frame of this study has meant that options with more radical interventions (such as alternative framing systems) could not be investigated due to the time which would be required for the design team to estimate material quantities for these fundamentally different design solutions.
- Assumptions and best practice values were adopted where possible when detailed information regarding the specification of materials was not available. For example, detailed information for internal walls/partitions, doors, finishes, FF&E and building services were not available at Stage 2, therefore GLA benchmark values have been used to estimate their embodied carbon impact at this early design stage of the project.

Appendix B - Model basis

B.1 Reporting requirements

Date of assessment	June - September 2021
Verified by	OneClick LCA
Project type	New build mixed-use building
Assessment objective	Embodied carbon assessment at practical completion and over life cycle of the British Library Extension aiming to reduce its carbon footprint through low carbon measures
Project location	London
Date of project completion	TBC
Property type	Mixed-use; Office, Lab, Library, Retail
Building description	The proposal will extend the northern aspect of the existing British Library with a new building to provide library accommodation (office, labs), commercial space, retail space and Crossrail 2 works at basement level.
Size	Modelled to a GIA of 89,101 m^2 (Alinea area schedule, 23-08-21)
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) Alinea Stage 2 cost plan (issued 21-06-21) Façade information provided by Arup Facades Secant piling volumes provided by Arup Structures Hard landscaping areas provided by DSDHA Discussions with the design team for any clarifications Alinea British Library area schedule (23-08-21)
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 there is a lack of detailed information.

B.2 Process

The diagram below describes the process followed to conduct the RIBA Stage 2 LCA for British Library Extension.

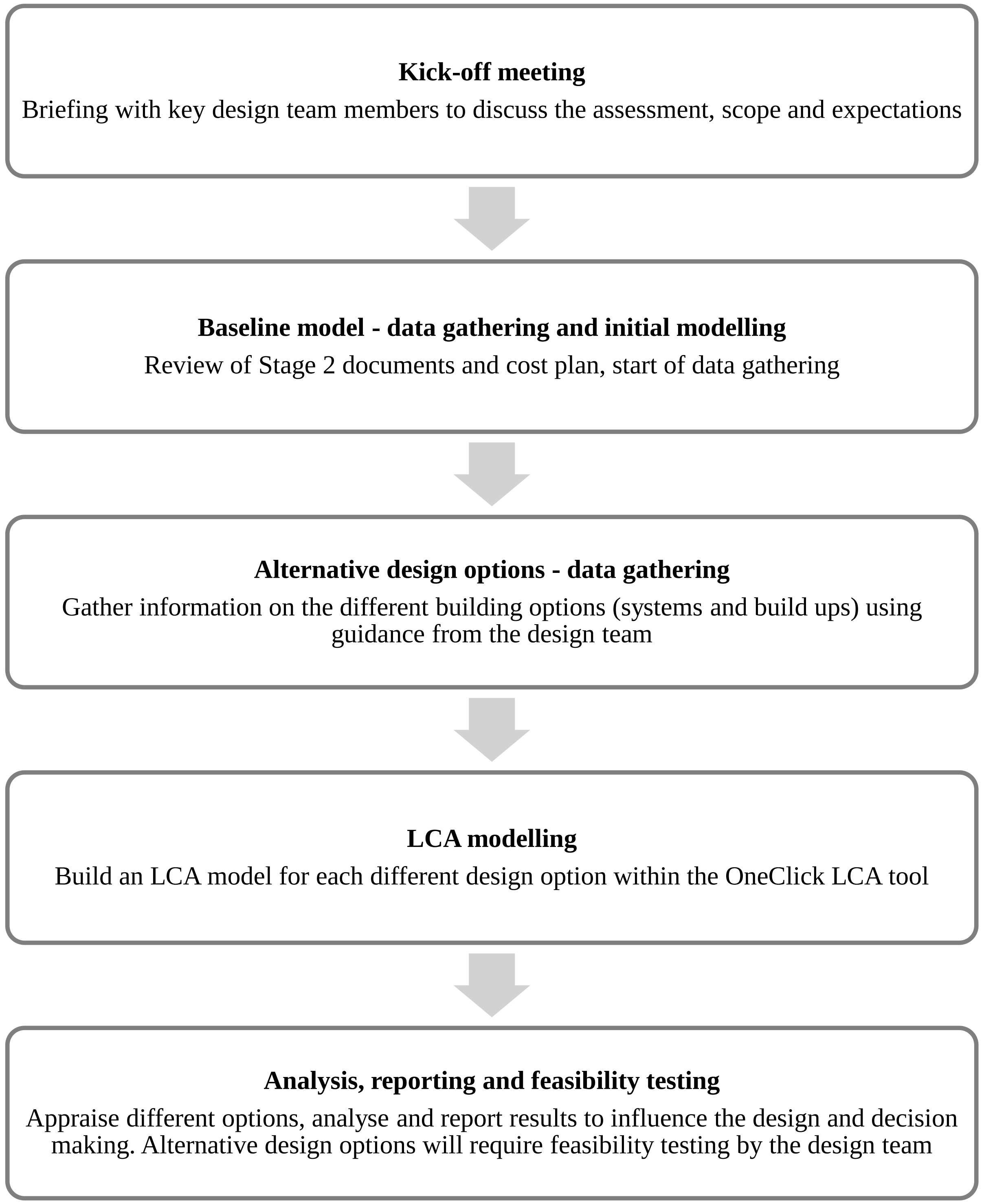


Figure 19 LCA process

B.3 RICS scope

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

Table 10 RICS-compliant in-scope elements for the RIBA Stage 2 analysis

Level 1	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	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	Fencing, railings and walls	1	Fencing and railings
				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		

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 in order 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.

Appendix D – BLCC Demolition Justification Report

Stanhope, Mitsui Fudosan UK, British Library

British Library Extension

BLCC Demolition Justification Report

Rev 3.0 | November 2021

Job number Job number

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Contents

1 Executive Summary

This report provides a whole life carbon-based justification for demolition of the British Library Centre for Conservation (BLCC) and temporary Story Garden on the British Library site at 96 Euston Rd, London.

Figure 1 The Application Site with the BLCC shown in blue

The demolition would form part of the Proposed British Library Extension, a new mixed-use development located to the north of the existing British Library in Somers Town, Camden (See Figure 1).

This document has been prepared in response to the requirements outlined in the Camden Planning Guidance (CPG) (2021) Energy and Efficiency - *Chapter 9: Reuse and optimising resource efficiency.*

Local Plan policy CC1 states that Camden Council require all proposals that involve substantial demolition to demonstrate that it is not possible to retain and improve the existing building; and expect all developments to optimise resource efficiency. Paragraph 8.17 of the Local Plan states this should be justified in terms of optimisation of resources and energy use.

This report, the Pre-Demolition Audit, and the Whole Life Carbon Assessment, collectively provide evidence that the above requirements have been met.

Key findings of this report are as follows:

- The existing BLCC is excluded from the Grade I listing that covers the British Library and is described in the list entry as ‘not part of the special interest’ of the library. Additionally, the BLCC has recently received a Certificate of Immunity from Listing (dated 5th October 2021).
- An Early Stage BLCC Retention Study undertaken by Allies and Morrison Architects found that the BLCC’s location within the development site creates a series of challenges in achieving some of the main project objectives.

- Notably, retention of the BLCC would restrict opportunities to create free-flowing pedestrian movement between existing and proposed library areas; force a densification of commercial development around the site perimeter; and reduce the daylighting levels reaching the BLCC's north lights, which are crucial to the conservation operation of the building.
- It was concluded that achieving the aspirations envisaged for the future Crossrail 2 station at Euston/St Pancras would not be possible without the demolition of existing buildings on the site, most notably the BLCC.
- A whole life carbon assessment over a 60-year time period has been carried out to compare the whole life carbon impact of the demolition versus retention of the BLCC. Results are summarised in Figure 2.
- This whole life carbon study demonstrates that there are carbon benefits over a 60-year lifespan from the demolition of the BLCC, versus its retention.
- It is anticipated that over 98% of waste can be diverted from landfill for the full demolition works at the British Library project (including the BLCC, pepperpot stair and internal alterations to the Library's north façade).
- The newly proposed BLCC will add significant value to the public realm, and the new community garden will positively contribute to the surrounding area.

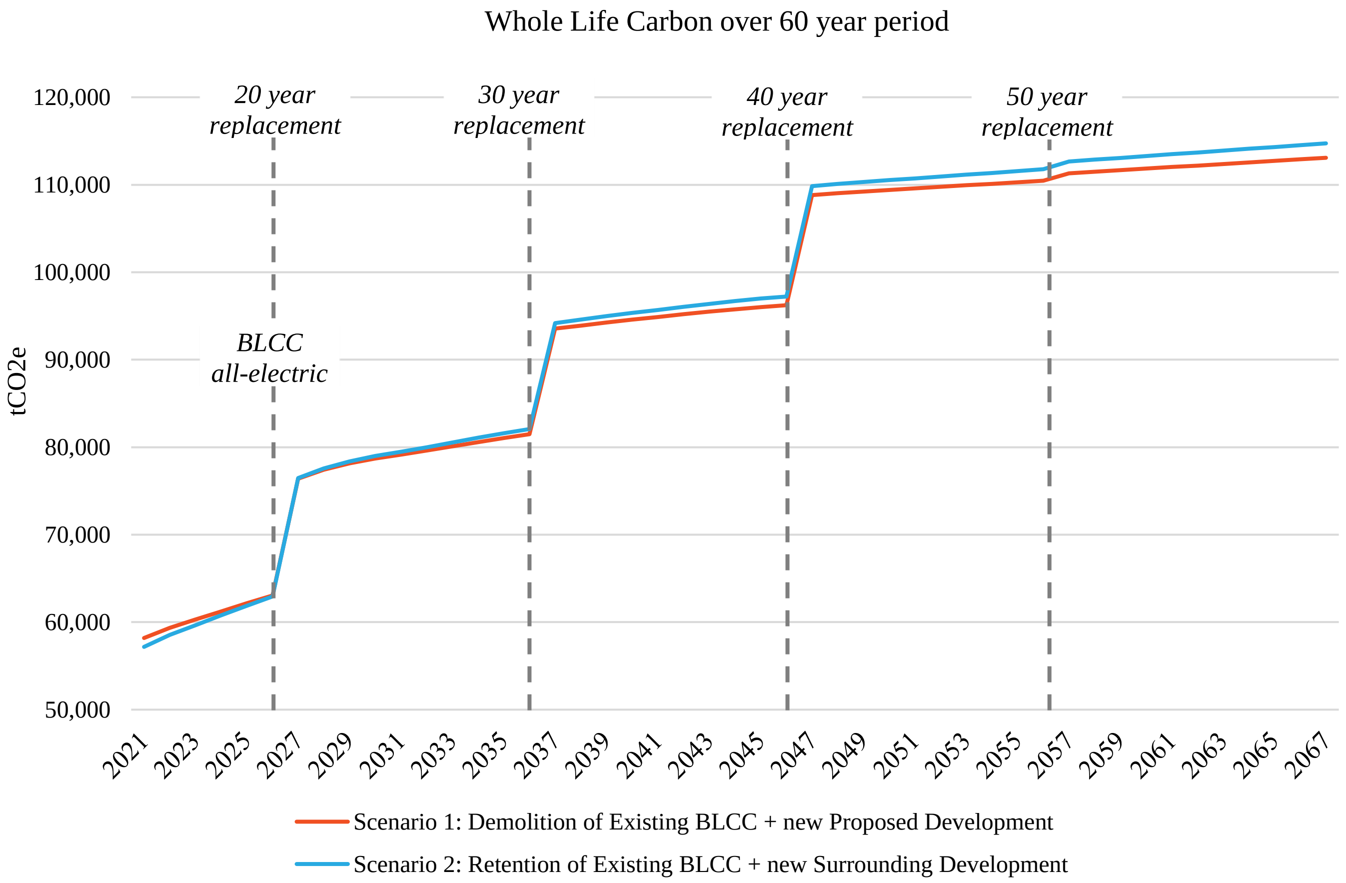

Figure 2 Whole life carbon emissions associated with Scenarios 1 and 2

2 Introduction

This report provides a whole life carbon-based justification for demolition of the British Library Centre for Conservation (BLCC) and temporary Story Garden on the British Library site at 96 Euston Rd, London.

The demolition of the BLCC and Story Garden would form part of the Proposed British Library Extension, a new mixed-use development located to the north of the existing British Library in Somers Town, Camden.

This document has been prepared in response to the requirements outlined in Camden Planning Guidance (CPG) (2021) Energy and Efficiency - *Chapter 9: Reuse and optimising resource efficiency.*

Local Plan policy CC1 states that Camden Council require all proposals that involve substantial demolition to demonstrate that it is not possible to retain and improve the existing building; and expect all developments to optimise resource efficiency. Paragraph 8.17 of the Local Plan states this should be justified in terms of optimisation of resources and energy use.

This report, alongside the Pre-Demolition Audit, and Whole Life Carbon Assessment, collectively provide evidence to support the case for demolition of the BLCC and Story Garden.

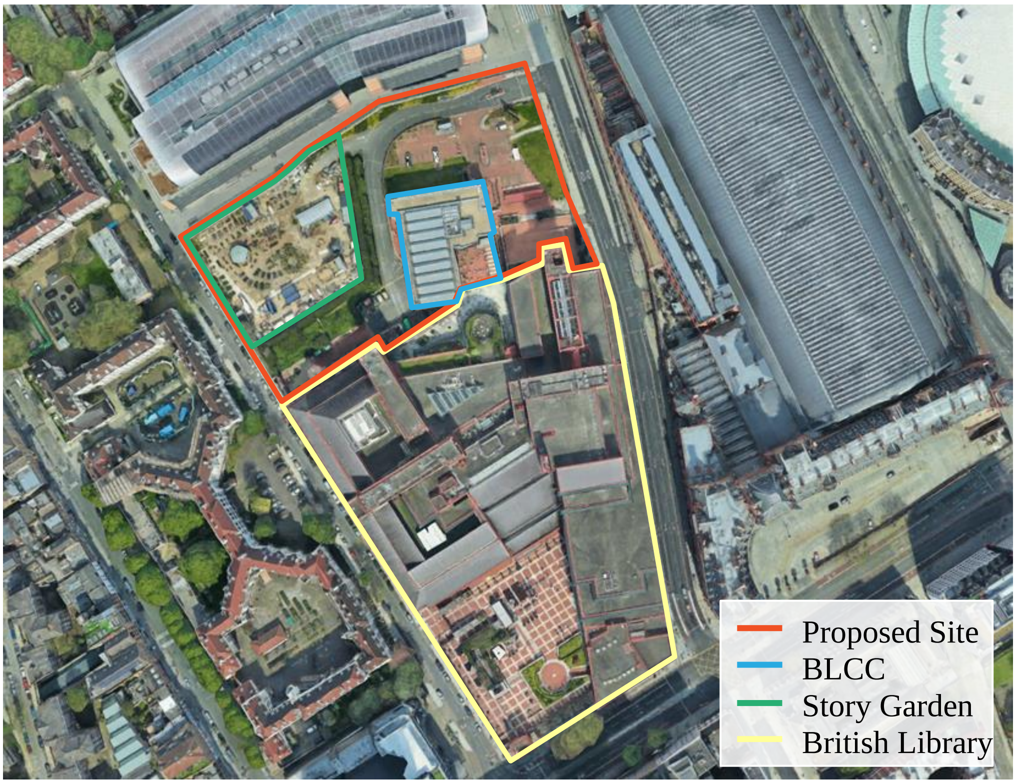

Figure 3 Aerial view of the Existing Site

The Proposed Development comprises of:

- British Library accommodation
- Commercial, including lab-enabled, floorspace
- Retail space
- Crossrail 2 works
- Relocated new British Library Centre for Conservation facilities

The Existing Site will need to be cleared in order to make way for the Proposed Development. As shown in Figure 3, this includes the British Library Centre for Conservation (BLCC) and the Story Garden, a temporary urban food growing garden built for and by the local community, which is run by Global Generation.

Although the Proposed Site forms part of the exiting British Library site, it has never been integrated into its campus. Currently, the existing British Library's plan terminates on its Northern range which houses the British Library Centre for Conservation, the Level 01 Terrace as well as the Library's loading bay, some staff parking and access roads.

There are notably no existing public connections at the northern side of the British Library and the library's internal circulation is truncated at this juncture and loops back on itself.

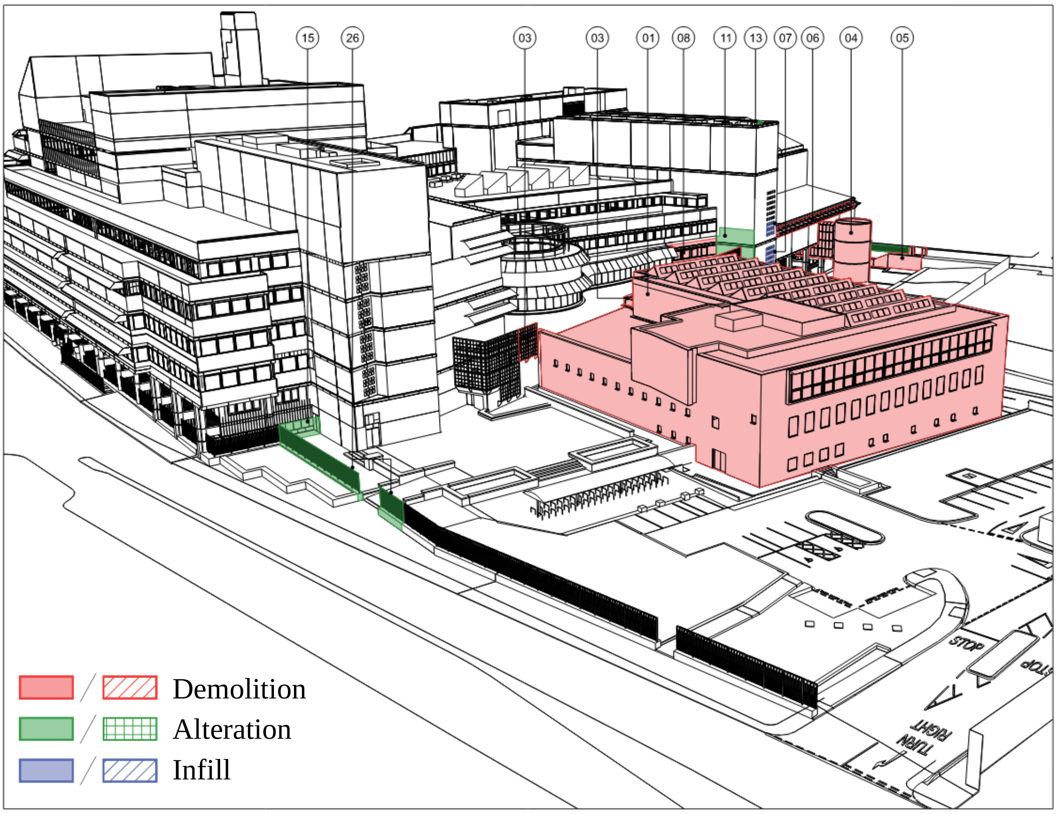

Figure 4 Existing building indicating areas of demolition/alteration (RSHP 31-08-21)

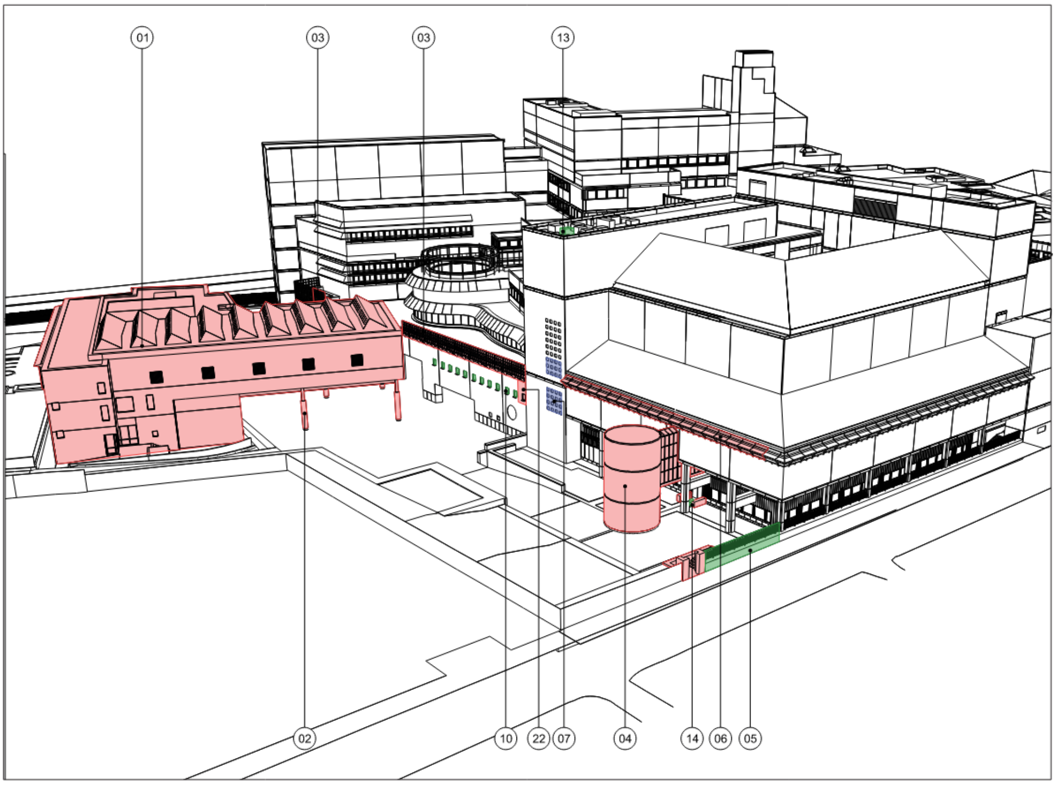

Figure 5 Existing building indicating areas of demolition/alteration (RSHP 31-08-21)

3 Existing BLCC

The 3-storey British Library Centre for Conservation (BLCC) designed by Long & Kentish architects was completed in 2007 and additionally houses the National Sound Archive (NSA). This building is connected to the original British Library building via an external deck above the library's loading bay.

The BLCC was constructed to a tight budget and a lower cost per square meter than the British Library, as a design and build contract. It was programmed as a back-of-house facility for the conservation of books and to house the BL's sound archive, with the public only able to access a small exhibition space near the entrance of the building of the first-floor terrace.

The BLCC architecture is subservient to the library and faced in matching red bricks. Its interior is more modest than that of the public areas in the British Library.

It is important to recognise that while the British Library is Grade I listed, the more recently constructed BLCC is excluded from the listing. The BLCC is described in the list entry as 'not part of the special interest' of the library. Additionally, the BLCC has recently received a Certificate of Immunity from Listing (dated 5th October 2021).

Figure 6 Aerial image showing the existing BLCC (left) and the British Library (right)

4 Existing Story Garden

The north-west corner of the existing site is currently occupied by the meanwhile Story Garden, a temporary urban food growing garden built in 2019 for and by the local community, which is run by Global Generation. The garden was approved under a temporary planning permission (ref: 2018/5663/P), to be relocated upon the commencement of construction for the Proposed Development.

Figure 7 Photograph showing the Story Garden (Source: Global Generation)

The Story Garden was created as a temporary space in partnership with the British Library, Stanhope and SMBL Developments Ltd. to make use of the unoccupied plot. It has provided a green social space in the heart of Somers Town whilst long-term plans for the site were drawn up.

As shown in Figure 7, the Story Garden consists of raised beds, a polytunnel, a series of portacabins, sheds, and a 5m circular wooden yurt. All built elements were brought to site with temporariness in mind, are portable and can be relocated. As a result, there is a negligible carbon impact from the removal of the Story Garden from its present site.

The Story Garden has proved to be a popular amenity for the local residents, a space for people to connect with nature and offering advice and education to assist with growing flowers, fruit and vegetables. It has also provided a safe environment in which to host community and calendar events and workshops, providing facilities through collaboration with local families, children and young people, local workers, companies and institutions.

The Project Team has committed to create a new community garden within the Site as part of the Proposed Development. This will be of high ecological value and create new biodiverse habitats in the area, whilst also mirroring the community-central approach and resulting value of the previous Story Garden. This is notable in the co-design approach to the Proposed Development's community gardens, as detailed in the Public Realm and Landscape Design Statement submitted as part of this application.

The removal of the temporary Story Garden from its present site is predicted to have a negligible carbon impact.

5 BLCC Retention

A study was undertaken to understand the impact of retention of the existing BLCC upon the Development Potential of the Site as part of the Invitation to Submit Final Tender. In line with the hierarchy provided in Camden's Energy and Efficiency CPG, this study considers the opportunities for *i. Refit, ii. Refurbish, iii. Substantial refurbishment and extension,* and *iv. Reclaim and recycle.*

A preliminary 'Proof of Concept' proposal, prepared by Allies and Morrison Architects, formed part of the original PQQ material. The SMBL Developments Ltd. team considered the possibility of BLCC retention and presented their thoughts to the British Library.

Site constraints

SMBL considered the possibility of BLCC retention. The three main factors preventing the retention of the BLCC were:

Firstly, the central plan position of the BLCC in relation to existing reading room wings serves to restrict to a large degree the opportunity to create free-flowing pedestrian movement between existing and proposed library areas.

The relatively solid form of the BLCC and the sensitivity of the activities which take place inside do not lend themselves to being surrounded by publicly accessible circulation areas. In effect, the BLCC acts as a 'bung' within the 'necking' formed by the rectilinear blocks of reading rooms located along the main street frontages.

Figure 8 Plan view of an early massing study exploring the retention of the existing BLCC

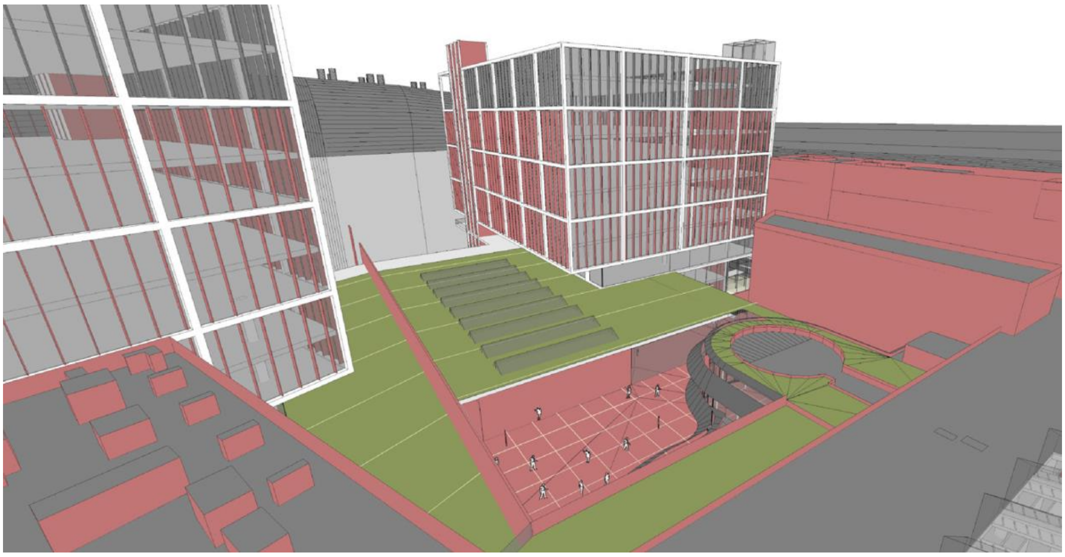

Figure 9 Massing study view of the existing British library terrace with retention of the existing BLCC

Secondly, retaining the BLCC presents challenges in realising the development potential of the site. Although relatively small and low, the central location of the BLCC leaves narrow residual areas of the site available for development which would require commensurately denser commercial development around the site perimeter.

For neighbours and adjoining owners, the perception and scale of such development runs counter to BL's aspiration for greater openness and transparency and may be counter-productive, pushing building heights into areas of greater impact and risk.

Thirdly, if the existing BLCC were to be retained within a new development of taller buildings surrounding it, it is doubtful whether residual levels of daylighting would remain sufficient to serve the building's north lights, crucial to the conservation operation of the building. This would not allow the BLCC to deliver the high-quality internal conditions required to realise its conservation ambitions.

For all of the above reasons, the base assumption of the Invitation to Submit Final Tender (ISFT) (competition) scheme assumed the removal and relocation of the BLCC elsewhere within the development site.

Assessment under Camden's CPG

Taking into account the condition of the existing building and feasibility of re-use as detailed above, assessment of the BLCC under Camden's Energy and Efficiency CPG hierarchy concludes the following:

i. Refit

Refit involves the retention of the existing structure as is, including minor works, and the replacement of building services to continue occupation of the building.

This option is not viable for the BLCC because a refit would not be sufficient enough to tackle the predicted lack of residual daylighting levels that will reach the BLCC if it is contained within a taller surrounding development. It was decided by the Project Team that a refit would not allow the BLCC to deliver the high-quality internal conditions required to realise its conservation ambitions.

ii. Refurbish

Refurbishment seeks to significantly improve the service life of the existing building. This option provides an opportunity to retrofit the building to reduce carbon emissions and include sustainable adaptation measures.

Refurbishment was considered by the Project Team as demonstrated within the BLCC retention study. It was concluded that refurbishment was not a viable option for the BLCC, because the reason for demolition is not related to poor building quality or limited service life, rather the BLCC creates a massing problem due to its prominent position on the Site of the Proposed Development.

iii. Substantial refurbishment and extension

Substantial refurbishment and extension takes into consideration the need to optimise site capacity and alter the existing structure to meet future needs.

This option is not viable for the BLCC because a substantial refurbishment and extension would not be sufficient enough to tackle the predicted lack of residual daylighting levels that will reach the BLCC if it is contained within a taller surrounding development, as was modelled in the BLCC retention scenario. This would not allow the BLCC to deliver the high-quality internal conditions required to realise its conservation ambitions.

Furthermore, in the case of extension, the relatively solid form of the BLCC and the sensitivity of the activities which take place inside do not lend themselves to being surrounded by publicly accessible circulation areas, which would be required if the proposal was to extend the existing buildings. Retention of the BLCC would restrict opportunities to create free-flowing pedestrian movement between existing and proposed library areas and in the case of extension would force a densification of commercial development around the site perimeter. Although relatively small and low, the central location of the BLCC leaves narrow residual areas of the site available for development.

iv. Reclaim and recycle

Given that the above options are demonstrated as unfeasible in the case of the BLCC, the Proposed Development has specified a Pre-Demolition Audit which identifies all materials within the BLCC and documents how they should be managed. This can be found appended to this document. The Pre-Demolition Audit prioritises re-use of waste on and off site, followed by waste recycling, and only finally specifies transportation to landfill.

Section 7 of this document details the whole life carbon study from the demolition of the BLCC, versus its retention. The study demonstrates that there are carbon benefits from the BLCC's demolition over a 60-year lifespan. Beyond this, the Circular Economy Statement submitted as part of this application demonstrates the Proposed Development's commitment to maximise reclamation and recycling across the project lifecycle.

Under Camden's Energy and Efficiency CPG hierarchy, this study concludes that *iv. Reclaim and recycle* (after demolition) is the most viable option for the Proposed Development.

The demolition of the existing BLCC and Story Garden, with commitment to maximise waste reclamation and recycling, is therefore considered an acceptable approach in order to enable greater social value in the Proposed Development and help realise its goals.

6 Integration of Crossrail 2

The proposals for the British Library Extension include a complex of structural enclosures above and below ground, to house the future requirements of Transport for London' Crossrail 2 (CR2) implementation.

Throughout the design process there have been ongoing discussions regarding the value of retaining the existing BLCC. For example, at the Design Review Panel No. 1 (23rd October 2020) the design team presented work in progress building upon the earlier scheme, updating LB Camden with latest work showing Crossrail 2 proposal and reinforcing earlier discussions which explained the need to remove and replace the existing BLCC in order to allow for the Crossrail 2 construction.

Crossrail 2 is planned to connect North and South London, and to run beneath the Library site. One of the most important advances anticipated in the Crossrail 2 strategy is the creation of a new station, beneath Somers Town, connecting Euston and St Pancras Stations, two of London's most strategic transport terminals. This forms a key aspect of the Proposed Development.

With the creation of this new transport infrastructure, the St Pancras area will become even more significant as London's most important transport interchange.

To create the new Crossrail 2 station, and make the connection between Euston and St Pancras, TfL require:

- A deep shaft at the western end of the site, descending from street level through 6 underground levels, to the future depth of the CR2 running tunnels. The shaft will connect to the running tunnels and platform of the new station, and house ventilation, escape and vertical transport infrastructure facilities, including escalators, when CR2 is eventually commissioned.
- A basement, to accommodate a series of plant rooms, including a large ventilation fan chamber, connecting to the deep shaft
- A pedestrian passageway connecting east-west across the site, at basement level, to provide a secure route for passengers between the new CR2 station platform and a new ticket hall under Midland Road (not forming part of the proposals)
- Ventilation, escape, servicing, and access facilities at street level and above, in a 'headhouse' and through ventilation funnels.

The scale, functions and arrangements of these elements have been the subject of three years' collaboration between Transport for London (TfL) and the Applicant.

The design, which forms part of the proposals for planning, is underpinned by a wealth of technical detail and engineering design that has established the technical viability and capacity of the shaft, basement, and passenger passageway to accommodate the future engineering installations and internal fit-out that will be carried out by Transport for London when Crossrail 2 is commissioned. Until then, the spaces created under the new building will be dormant.

Given this context, it was therefore concluded that achieving the aspirations envisaged for the future Crossrail 2 station at Euston/St Pancras would not be possible without the demolition of existing buildings on the site, most notably the BLCC.

7 BLCC Whole Life Carbon Study

This section demonstrates that under the assumptions outlined in this assessment, there are carbon benefits over a 60-year lifespan from the demolition of the BLCC, versus its retention – even considering a conservative approach to analysis. Due to the relatively small size of the BLCC, its demolition does not have a substantial impact on the carbon footprint of the whole development.

Scenarios

A whole life carbon assessment over a 60-year time period has been carried out to compare the whole life carbon impact of the following scenarios:

Scenario 1: The demolition of the existing BLCC + construction of the Proposed Development

Scenario 2: The retention of the existing BLCC + construction of a new Surrounding Development, which would be constructed around the existing BLCC.

Data

The whole life carbon study combines the following data:

- Operational energy consumption of the existing BLCC
- Predicted operational energy consumption of the Proposed Development based on the current Energy Statement
- Embodied carbon from the demolition of the existing BLCC and re-use of materials as specified in the Pre-Demolition Audit
- Embodied carbon of the Proposed Development
- Embodied carbon of material replacement cycles over the 60-year life span based on the LCA (presented as part of this planning application)
- ‘End of life’ embodied carbon data based on the LCA (presented as part of this planning application)

In Scenario 2 (retention of the existing BLCC) an assumption has been made for the GIA of a hypothetical new Surrounding Development which would be built around the retained existing BLCC. The GIA values used in this study are detailed in Table 1.

Table 1 Gross internal areas

	GIA (m^2)
Existing BLCC	2,672
New Surrounding Development	87,500
New Proposed Development	89,451

Operational energy in the existing BLCC

Operational energy figures for the existing BLCC have been provided by the British Library. The existing BLCC has an average energy consumption of 262,390 kWh per annum. This is split into electricity and gas. On average, the energy consumed is sourced from 88% electricity, and 12% gas. In winter months the gas use can be as high as 23% of the overall operational energy consumption.

The operational energy consumption of the existing BLCC is incorporated into the whole life carbon study. It assumes an average energy consumption of 146,611 kWh (electricity) and 115,779 kWh (gas) per annum.

All-electric energy

Although the operational energy consumption of the existing BLCC is presently a combination of gas and electric, it is anticipated that the gas contribution would be phased out within the 60-year lifespan of this study.

Within the whole life carbon study, an assumption has been made that in the year 2027, the existing BLCC would be retrofitted to operate as a fully electric building. The year 2027 was selected as the BLCC was constructed in 2007, and under the RICS Professional Statement guidance, MEP systems have a 20-year expected lifespan. The model has assumed that the kWh demand has remained consistent, and the efficiency of the systems proposed to meet the demand have been upgraded from 96% for the gas boilers to 300% for likely new Air Source Heat Pumps.

The transition to fully electric systems follows the expected evolution of building regulations and the requirements to decarbonise the existing building stock. When the life spans of the current MEP systems come to an end, the new systems will need to comply with stricter net zero carbon requirements. This will be met by increased dependence on a decarbonised electricity grid, so any new MEP system is assumed to be fully electric.

Decarbonisation

The operational carbon data for the Proposed Development has been provided by Arup and is detailed within the Energy Statement for the Proposed Development. The data is based on the UK Building Regulation Part L analysis Arup have undertaken of the current Stage 2 design.

This whole life carbon study has been modelled to account for UK grid decarbonisation forecasts.

Adjustment coefficients calculated from the FES 2021 ‘slow progression’ scenario for a 60-year lifespan have been applied to the operational carbon figures provided for both the Proposed Development (Scenario 1) and new Surrounding Development (Scenario 2).

Replacement cycles

Assumptions for the lifespan of different building elements follows guidance set out in the RICS Professional Statement. These are detailed in Table 2.

These assumptions have been incorporated into the whole life carbon study to ensure the embodied carbon associated with replacement is accounted for.

Table 2 Component lifespan assumptions

Building element	Lifespan (years)
Superstructure (only select elements)	30
Façade	30
Internal walls and partitions	30
Internal finishes	20
FF&E	10
Building services	20

Pre-Demolition Audit forecasts

The Pre-Demolition Audit has identified the key materials that will arise as a result of demolition and associated works on site.

Key materials identified include concrete, hardcore, tiles and ceramics, metals, timber, gypsum (plasterboard), plastic and glass, for which the most suitable waste management options have been determined in order to maximise the recovery of each of the materials.

The findings also include a forecast tonnage or volume of each of the key materials that are anticipated to arise from the demolition. This WLC assessment includes the embodied carbon impact of the demolition and processing of all the materials identified in the pre-demolition audit (Modules C1-C4). These quantities have also been modelled in Table 3 (A1-A3) to calculate the anticipated carbon footprint of the materials that may be reused in the new development.

Table 3 The carbon footprint of materials from the demolition of buildings on site, as forecast within the Pre-Demolition Audit

Demolition materials	**Cradle to gate impacts (modules A1-A3)**	
	tCO_2e	**% of total**
Metals	3,434	54.70%
Soft floor coverings	1,180	18.80%
Concrete	422	6.70%
Brick	288	4.60%
Gypsum plaster board	262	4.20%
Furniture	253	4.00%
Insulation	207	3.30%
Discarded equipment and machinery	187	3.00%
Plastic	20	0.30%
Glass	8.6	0.10%
Cables	7	0.10%
Timber	2.5	000%
Hardcore	2.6	0.00%
Mixed demolition aggregate	0.3	0.00%
Tiles and ceramics	0.075	0.00%

There is a potential opportunity to re-use some of these materials on site, which would reduce the volume of materials to be sourced in the Proposed Development. This could provide significant carbon savings.

The results of the study are shown in Figure 10. Note that the vertical axis of the graph starts at 50,000 tCO2e.

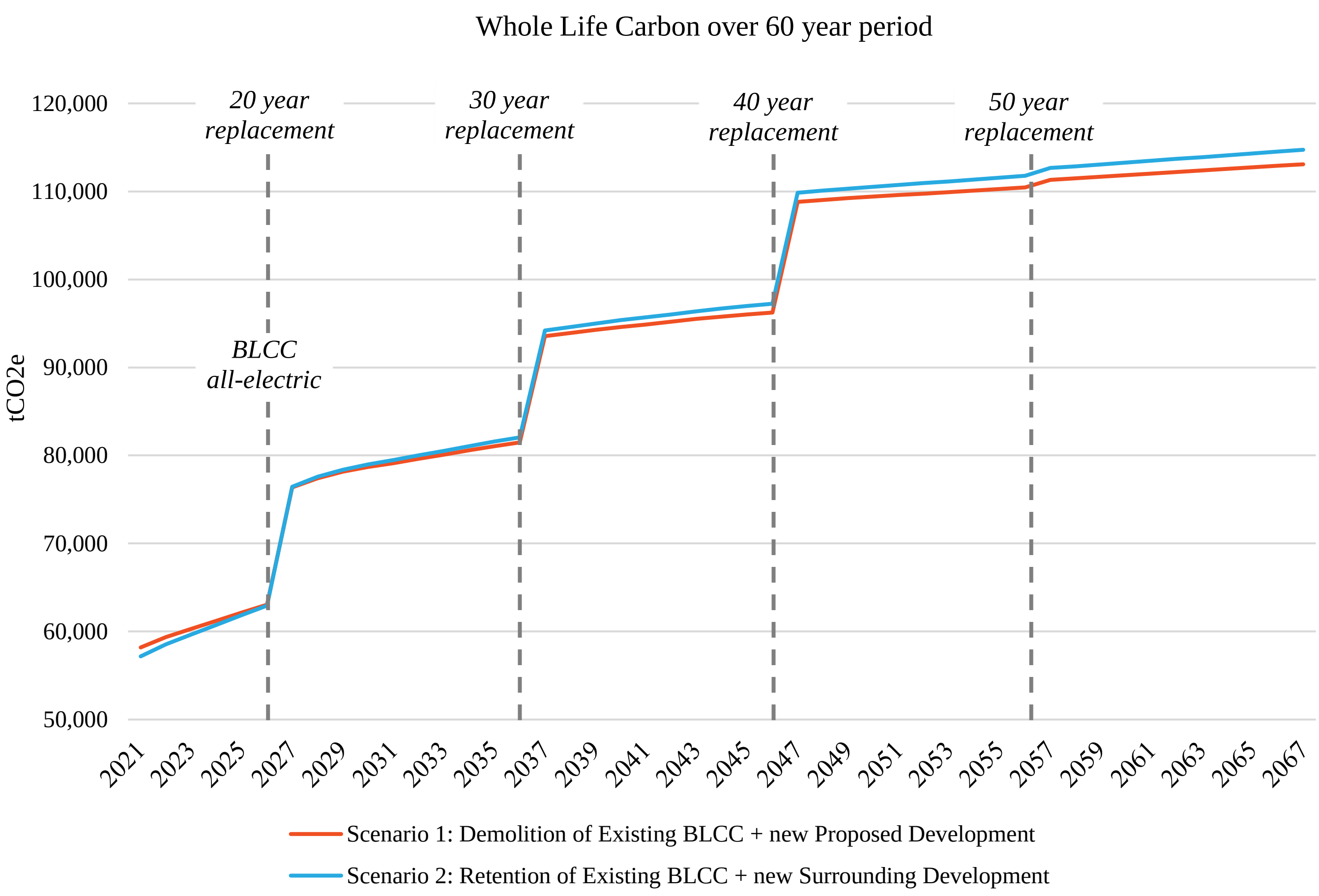

Figure 10 Whole life carbon comparison over the building's 60-year life span (from 2007)

A comparison of the carbon emissions of the two scenarios is shown in Table 4.

Table 4 Cumulative carbon emissions comparison between Scenarios 1 and 2

	Cumulative carbon emissions (tCO2e)		
	2027	2047	2067
Scenario 1 (demolition)	76,385	108,816	111,318
Scenario 2 (retention)	76,460	109,841	112,658
Carbon impact of retaining the BLCC (Scenario 1 – Scenario 2)	+ 75	+ 1025	+ 1340
% reduction in cumulative carbon emissions between Scenario 1 (demolition) and Scenario 2 (retention)	0.10%	0.93%	1.19%

This assessment has not included the impact on operational performance that a future retrofit of the BLCC could have. It is difficult to predict the scale of this potential improvement over time, however we can predict that a future improvement to the thermal performance of the BLCC to match the levels achieved within the Proposed Development would reduce the operational energy, but not significantly enough to revert the initial trend.

The key findings from this study are as follows:

- Scenario 1 (BLCC demolition) has a lower whole life carbon impact over a 60-year study period than Scenario 2 (BLCC retention). The reason for this is two-fold. The existing BLCC depends on an electric/gas split, of which the gas proportion accounts for a higher operational carbon figure per annum than an all-electric comparison. Over the span of the assessment, even accounting for an MEP system upgrade to all-electric, the higher operational figure outweighs the additional carbon cost of the demolition process.
- By 2067, Scenario 1 (BLCC demolition) offers a reduction of **1.19%** over Scenario 2 (BLCC retention), which accounts for a total saving of **1340 tCO2e.**
- While initially Scenario 1 (BLCC demolition) has a higher whole life carbon footprint, by the year 2027, both Scenarios 1 and 2 demonstrate equal whole life carbon footprints. From the year 2027 onwards, Scenario 1 has a lower whole life carbon footprint than Scenario 2.
- Over the full 60-year study period, the carbon difference between the two schemes continues to increase, implying that Scenario 1 (BLCC demolition) will offer even greater savings over the long run.

The calculations of the carbon emissions have assumed that the relative operational and embodied carbon impacts (kgCO2e/m^2) of both the Proposed Development and Surrounding Development scenarios are comparable.

However, in reality, a development designed to surround the existing BLCC building would experience significant site constraints that would likely create a building that is less carbon efficient than a new building developed without those constraints.

This whole life carbon study demonstrates that there are carbon benefits over a 60-year lifespan from the demolition of the BLCC, versus its retention.

8 Demolition Plan

In order to facilitate the construction of the Proposed Development, the BLCC would be relocated. The BLCC functions are integral to the operations of the British Library and therefore would be temporarily accommodated within the existing Library until the relocated BLCC facility is completed.

Although the existing Story Garden will be removed, a new community garden would be created within the Site. This would be of high ecological value and create new biodiverse habitats in the area.

It is recognised that there would be a delay between the closure of the Story Garden and the completion of the new community garden. However, discussions are ongoing so as to provide a continuation of the community service, by identifying projects within the local area that could be undertaken during the construction period.

The Proposed Development will re-use as many key recyclable elements from the demolition as possible in the construction of the new library.

Please refer to both the Pre-Demolition Audit and the Circular Economy Statement completed and submitted as part the application for further details on the materials that have the potential to be re-used and the team's commitments to re-use them.

The Pre-Demolition Audit has been carried out during Concept Design stage prior to any strip out. This early-stage intervention is critical in ensuring all contractors can contribute to maximise rates of waste re-use, recycling and diversion from landfill.

Key takeaways from the Pre-Demolition Audit are as follows:

The structure of the BLCC broadly consists of:

- 3-storey steel frame consisting of LG, G, 1st & Roof with large steel beams supporting terrace
- Reinforced concrete slabs (poured in-situ floors & precast planks for roof support)
- External walls of Insulated Metsec with facing fletton brick
- Apexes at roof level are zinc & glass
- 2nr reinforced concrete stair cores (fire escapes)
- Block walls separating plant rooms

A range of sustainability measures must be implemented by the contractor in the proposed development including:

- Plant and equipment salvage - The specification of the equipment and plant to be removed from site needs to be checked and evaluated for compliance with legal requirements so they can be reused in another project
- Waste - Encourage and assist the project delivery team to reduce, reuse, and recycle all non-hazardous waste on-site/off-site
- All sustainability measured KPI's will be logged, recorded and communicated at regular intervals using a dedicated SMARTWaste management tool

Materials holding a high recycling potential have been identified within the Pre-Demolition Audit, and it is anticipated that over 98% of waste can be diverted from landfill for the demolition works at the British Library project (including the BLCC, pepperpot stair and internal alterations to the Library's north façade).

9 Proposed BLCC

The Proposed Development seeks to integrate the BLCC facility more closely with the inner workings of the library where the visibility of activities taking place can form a key part of the outreach programme of the library itself. This contrasts the existing BLCC is currently accessible to the public only via the external terrace at Level 01 on Ossulston Street.

Figure 11 Proposed View of the new BLCC from Ossulston Street

The demolition of the BLCC would require the removal of the pepperpot stair, a cylindrical brick enclosure containing escape stairs and bridge links to office accommodation and reading rooms at upper ground floor and level 01 respectively. However, in the Proposed Development, the stair will be relocated to a new position on Ossulston Street which corresponds with part of the site anticipated for extension in original design drawings by Colin Wilson.

The form of the new BLCC extends the massing, articulation and materiality of the Ossulston Street frontage, taking cues from height datums found in the existing building. Set-backs at lower ground and upper ground floors continue that of the Proposed View from Ossulston Street perimeter colonnade, with the more solid brick enclosure of the Humanities reading room echoed in the conservation studio. PPC/painted metal horizontals pick up on existing horizontal datums.

A glazed clerestory at roof level takes advantage of greater height offered by the proposed transfer structure of the adjacent extension and corresponds to the height on Ossulston Street of the existing red cornice, quietly announcing a more contemporary presence. The existing cornice is terminated on the north elevation by a full-height brick recess containing the BLCC service core which provides an interruption to the frontage; its proportion resembling the proportion of existing rectilinear brick projections found throughout the library.

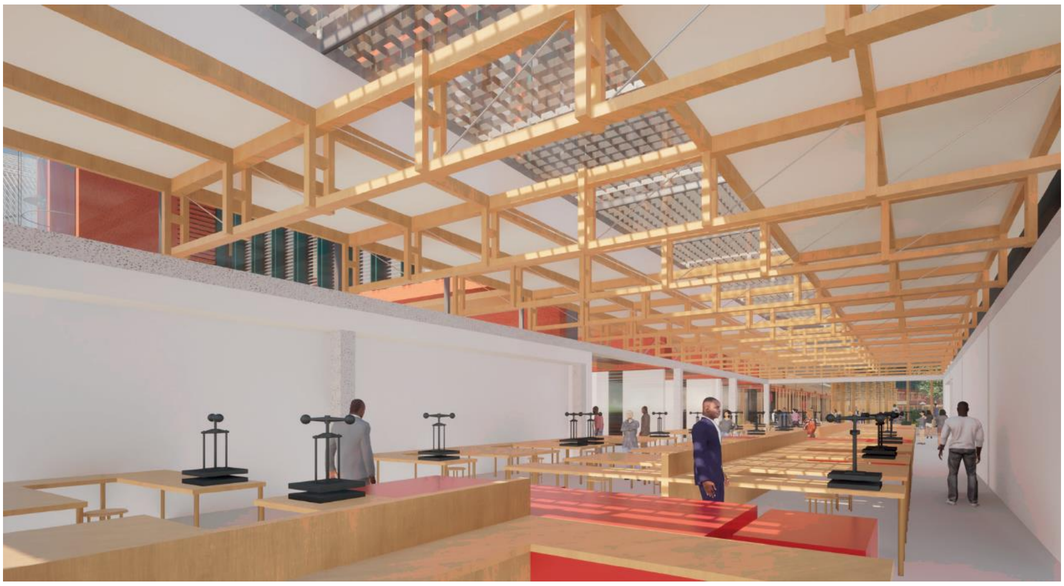

Figure 12 Illustrative view of main BLCC conservation studio looking east

Figure 13 View looking South towards Ossulston Street

The sustainability performance of the proposed British Library Extension will be benchmarked using the Building Research Establishment Environmental Assessment Method (BREEAM) New Construction 2018. The bespoke BREEAM pre-assessments for the office, culture, laboratory and retail areas will set the proposal above and beyond typical buildings, and a minimum target of an Excellent rating with an aspiration for Outstanding emphasises the project value.

For further details on the value of the Proposed Development, please see the Sustainability Statement and also the Social Value Report which were both submitted as part of this application.

10 Proposed Community Garden

As part of the planning application a community and co-design strategy has been developed which identifies how the existing story garden on site can be provided again, designed to suit the needs of the users of the local neighbourhood and connect to the wider community gardens and green spaces in Somers Town.

The landscape and public realm proposals for the site include new Community Garden spaces on the west side of the site, close to the Ossulston Street entrance to the new extension building. DSDHA have worked with Global Generation to research and analyse the site context with regard to local initiatives and community projects.

A ‘hub and spoke’ model has also been developed which sees the Community Garden at the British Library Extension as a ‘hub’ which can support ‘spokes’ (various learning and greening initiatives) across Somers Town. Further detail on plans for community engagement and consultation on this aspect of the landscape and public realm at the British Library Extension is given in the Public Realm and Landscape Design Statement submitted as part of this application.

The site is currently disconnected from the many surrounding green spaces, minimising the ecological value of it as a space. Although there are pockets of habitat within the current site, there is significant scope and opportunity to increase these size and variety of habitats in the future proposals.

By providing new habitat types that are not present the development, the proposal can enhance the area’s biodiversity and also better connect the wider green space network by creating islands in the urban neighbourhood for bugs and birds to use as stepping stones. These islands will also have the effect of significantly greening the site for its human users and contributing to their wellbeing.

11 Conclusion

Conclusively, it has been demonstrated across a range of considerations, that the demolition of the existing BLCC and Story Garden on the proposed site will have a positive contribution on the overall British Library extension.

Key outcomes are as follows:

- The existing BLCC is excluded from the Grade I listing that covers the British Library and is described in the list entry as ‘not part of the special interest’ of the library. Additionally, the BLCC has recently received a Certificate of Immunity from Listing (dated 5th October 2021).
- Retention of the BLCC would restrict opportunities to create free-flowing pedestrian movement between existing and proposed library areas; force a densification of commercial development around the site perimeter; and reduce the daylighting levels reaching the BLCC’s north lights, which are crucial to the conservation operation of the building.
- It was concluded that achieving the aspirations envisaged for the future Crossrail 2 station at Euston/St Pancras would not be possible without the demolition of existing buildings on the site, most notably the BLCC
- This whole life carbon study demonstrates that there are carbon benefits over a 60-year lifespan from the demolition of the BLCC, versus its retention.
- It is anticipated that over 98% of waste can be diverted from landfill for the full demolition works at the British Library project (including the BLCC, pepperpot stair and internal alterations to the Library’s north façade).
- The newly proposed BLCC will add significant value to the public realm, and the new community garden will positively contribute to the surrounding area.

This report, alongside the Pre-Demolition Audit, and Whole Life Carbon Assessment, collectively provide evidence that the requirements detailed in Camden Planning Guidance (CPG) (2021) Energy and Efficiency - *Chapter 9: Reuse and optimising resource* efficiency, have been met.

Appendix E – Cost consultant's letter

1. Background / Scene Setting

alinea has provided the quantities for some specific elements of the design for the purposes of WLC assessment. These were limited to the items that could be measured given the design stage.

It is typical for a project at this early stage of design to have limited items that are "quantifiable" with other suitable allowances made for the anticipated design. These are typically included as lump sum "allowances" or £/ft2 rates.

It is understood that the Quantity Surveyor is required to verify the input of quantities into the WLC assessment. Given the above we have prepared a summary to help indicate how much of the project can be quantified at this stage.

The below is a summary of the final commercial only Cost Model illustrating the monetary value of the items for which quantities have been provided to help indicatively show potential further provisions that should be made by "others".

2. Key documents

The documents as listed below form the basis of this assessment and should be read in conjunction with this summary.

- "Provisional Quantities for LCA Use Only" dated 16 July 2021
- "Indicative Order of Cost "Planning Light" Stage" dated 13 September 2021 (commercial cost model only)

3. Assessment

It is understood that for the purposes of WLCA's that only building elements need to be assessed. All preliminaries, CM Fee, contingency and inflation provisions are excluded from the assessment. It is also understood that works associated with the Cross Rail shaft are to be excluded from the assessment. In the first instance we have stripped the costs associated with these elements out and created a baseline for which costs are "applicable".

	Total Cost Model	"Not applicable"	Applicable	Value where qts have been provided	Explanation
Enabling works / site clearance / site remediation	5,900,000	1,260,000	4,640,000	0	Costs are associated with demolition, land clearance, etc
Utilities	7,200,000	1,000,000	6,200,000	0	General allowances for services only
Public Realm incl. pavillion to the west	12,750,000	2,650,000	10,100,000	0	Costs measured as general £/m2 allowances
Loading bay works	5,600,000	1,200,000	4,400,000	0	Costs measured as general £/m2 allowances
CR2 shaft works	38,700,000	38,700,000	0	0	Not applicable
Main Building; basement, podium, upper floors	327,400,000	69,900,000	257,500,000	87,300,000	Quantities provided for concrete, reinforcement, steel, facades as quantifiable
Cat-A fit out (incl. ATI)**	34,250,000	6,900,000	27,350,000	0	Costs are based on £/ft2 allowances only
BLCC (shell and core, fit out and move into existing building)**	26,780,000	5,400,000	21,380,000	0	Costs are based on £/ft2 allowances only
Tank Farm	1,500,000	300,000	1,200,000	0	Key costs are associated with plant only
Library plant	9,500,000	2,000,000	7,500,000	0	Costs are associated with plany only
Library area outside the site boundary**	670,000	100,000	570,000	0	Costs are based on £/ft2 allowances only
General phasing	500,000	500,000	0	0	Not applicable
Construction period inflation	16,500,000	16,500,000	0	0	Not applicable
Total Cost Model excl. below the line items	**487,250,000**	**146,410,000**	**340,840,000**	**87,300,000**	
% of the costs associated with quantities measured				**26%**	

** For items that are £/ft2 allowances only, a notional adjustment of 20% has been stripped out to account for on costs on these elements

In financial terms we have provided quantities for c26% of the current design for which the assessment is applicable. We can confirm that we have reviewed the input of these specific quantities and can confirm that of the quantities we have provided at least 95% have been incorporated into the WLC assessment with interpretation / enhancement as necessary.

We understand that the current assessment is based on the scheme "as drawn" with benchmark provisions for various elements but that it does not hold any contingencies for the development of the design, quantities increasing, items becoming measurable (eg secondary items, temporary works, resolution of other £.ft2 provisions), etc. We would simply note that given this transparent approach the assessment will increase as the items are resolved.

Addendum: Compliance with GLA Updated WLCA Guidance

This Addendum is provided in response to the updated GLA Guidance which was issued in March 2022 alongside complementing the original report. Following this issue, the GLA published and formally adopted the London Plan Guidance: Life Cycle Assessment. This supersedes the previous Draft for Consultation version (October 2020) in setting out the requirements for Life Cycle Assessments submitted to GLA to support applications for referable development.

Alignment with updated GLA Guidance

Area of compliance	Arup response/ Actions taken
London Plan: The London Plan now includes new carbon, energy and heat risk policies (See Policies SI 2, SI 3 and SI 4). Please ensure that you are aware of these new policies in preparation for submitting your planning application. The latest status of the new London Plan can be found here: https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/what-new-london-plan.	No response required
Guidance: Applicants should follow the GLA 'Whole Life-Cycle Carbon Assessments Guidance - draft for consultation' 2020 and the GLA WLC assessment template (https://consult.london.gov.uk/whole-life-cycle-carbon-assessments) which should be completed in full. These documents set out the information that should be provided within the Whole Life-Cycle Carbon Assessments to be submitted at Stage 1. Applicants should ensure they are familiar with the new guidance in preparation for submitting their planning application.	This addendum responds to the requirements of the new guidance.
The following comments summarise key points on responses for Whole Life-Cycle Carbon Assessment principles at the detailed planning stage, but you should refer to the guidance for full details.	No response required
General compliance comments	
The applicant has provided all information within the project details section of the template under the Detailed planning stage, in line with the GLA Whole Life-Cycle Carbon Assessment guidance document.	Compliant - please refer to Appendix B 1.
The assessment method stated does conform with BS EN 15978 and 'RICS Professional Statement and guidance, Whole Life carbon assessment for the built environment' (RICS PS) as set out in the GLA Whole Life-Cycle Carbon Assessment guidance document.	Compliant - please refer to Executive Summary.
The applicant has confirmed that the operational modelling methodology for Module B6 results follow TM54.	Commitment confirmation (see below): Pre-planning, TM54 modelling has not been undertaken due to early stage of design development. However, the project is committed to the use of the Design for Performance methodology during design development, with a target

Area of compliance	Arup response/ Actions taken
	NABERS rating of 4.5* for the base building. The NABERS modelling will be used to report unregulated energy demand when the WLCA is updated post-construction. please refer to Section 2.1.
The assessment has been completed with a reference study period of 60 years.	Compliant - please refer to Section 1.1.
The software tool used is as per the list of suitable software tools in Appendix 1 of the GLA Whole Life-Cycle Carbon Assessment guidance document and does align with the software tool used at the outline planning stage.	Compliant - please refer to Appendix A 3. OneClick software was used.
The source of carbon data for materials and products, and EPD database stated within the assessment does come from acceptable sources as set out in the GLA Whole Life-Cycle Carbon Assessment guidance document.	Compliant - please refer to Appendix B 1. OneClick database of EPDs was used.
The applicant has confirmed that 95% of the cost allocated to each building element category has been accounted for in the assessment.	Compliant - This has been coordinated with the Quantity Surveyor, who will prepare a statement confirming that more than 95% of the quantities that they provided for assessment have been included in the model. The quantities provided by the Quantity Surveyor were complemented with further information from the Design Team for the building components not included in the planning cost plan. See Section 1.3 for details.
Third party assurance of the WLCCA: Required as best practice The applicant has provided explanation of the third-party verification mechanisms that have been adopted to quality assure the assessment.	Best practice third-party verification following the updated guidance was not completed within the submission documentation. The following verification and assurance processes, which includes third parties outside Arup, were followed to ensure accuracy and quality of results: - **Info gathering stage**: Regular workshops with technical disciplines and Quantity Surveyor to ensure accuracy of quantities and specification following design development. - **Modelling stage**: Model and report developed by experienced carbon consultants with support from senior consultants. Assumptions checked with the wider Design Team. - **Document verification and review**: Deliverables are reviewed by Senior Consultants and Directors. Comment and modification phase before final deliverable is issued of Project Team comments. - **External Design Team review**: The approved deliverables are issued to the whole project team for comment, including technical consultants, planning consultant and SMBL.
The applicant should either submit or give permission for the GLA to submit the assessment to the Built Environment Carbon Database.	Additional commitment (see below): SMBL provides permission to submit assessment to the Built Environment Carbon Database.
Estimated WLC emissions	
The applicant has provided results that cover all of the main lifecycle module groups (A1-A5, B1-B5, B6-B7, C1-C4 and D).	Compliant - please refer to GLA LCA spreadsheet.

Area of compliance	Arup response/ Actions taken
The applicant has provided results that fall within the WLC benchmarks and has reasonably explained the reasons for any divergences from the WLC benchmark.	Compliant – The building A1-A5 emissions are 635 kgCO2/m2, close to 40% reduction from current practice and therefore, aligned with best practice according to the GLA benchmarks. Please refer to Section 2.4.
New methodology to calculate B2 and B3 emissions.	Additional commitment (see below): Existing appendix will be updated to report emissions B2 and B3 separately.
Retention of existing buildings and structures	
The applicant has confirmed that options for retaining the existing buildings and structures have been fully explored before considering substantial demolition by providing reference to relevant studies. Option appraisal: Options for retaining existing buildings and structures to ben fully explored before considering substantial demolition. If substantial demolition is proposed, applicants will need to demonstrate that the benefits of demolition would clearly outweigh the benefits of retaining.	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab). The response is detailed in Appendix D of the submitted WLCC: "BLCC Demolition Justification Report". This document is a 'Condition and Feasibility Study' of the existing buildings and proposed demolition that responds to Camden's Planning Guidance 'Energy efficiency and adaptation'. This Report justifies qualitatively and quantitatively why 'Refit', 'Refurbish', and 'Substantial refurbishment and Extension' scenarios are not viable for this project due to the site constrains. The format of the assessment is different because it responds to Camden's CPG, but the content is comparable to the requirements of the updated Guidance from the GLA. Therefore it is not proposed to update the existing report.
Reuse of existing / demolished materials: Provide an estimate of the percentage of the new build development which will be made up of existing façades, structures, and buildings.	Additional commitment (see below): Calculate the estimated percentages of reuse with more granular information at Stage 3.
Key action and further opportunities to reduce whole life-cycle carbon emissions	
The applicant has provided constraints but should also provide details of the site opportunities in reducing WLC emissions.	Compliant - please refer to Section 4.
The applicant should provide an estimation of the WLC reduction ($kgCO_2e/m^2$ GIA) for all actions and further potential opportunities stated within the template.	Compliant - please refer to Section 4, Table 7.
Material Quantity, assumptions and end of life scenarios	
The applicant should complete the material quantity and end of life scenarios table in full.	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab).
All material types and quantities have been provided for all the applicable building element categories but do not seem to align with the Assessment table.	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab).
Assumptions made with respect to maintenance, repair and replacement cycles (Module B) have been stated.	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab).
Material 'end of life' scenarios (Module C) have been filled out for all applicable significant materials.	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab).

Area of compliance	Arup response/ Actions taken
The applicant shas provided an estimated mass (kg) of reusable and recyclable materials for each building element category.	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab).
The applicant has provided details of the refrigerants (name, charge, annual leakage rate, GWP, end of life recovery rate).	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab).
MEP: Detailed modelling recommended.	Additional commitment (see below): There was not enough information pre-planning on quantities and products to model some building components, including MEP. New commitment is adopted below to calculate the embodied carbon impact of MEP at Stages 3-4, when the MEP systems are sufficiently defined to allow granular modelling. BREEAM requires that an LCA be undertaken at Technical Design Stage, when sufficient design development has occurred to allow MEP to be calculated.
GWP potential for all life-cycle modules	
The applicant has completed the template table completely.	Compliant - please refer to GLA LCA spreadsheet ("Detailed planning stage" tab).

Additional commitments of British Library Extension

Retention of existing buildings and structure: The Design Team commits to providing an estimate of the percentage of the new build development which will be made up of existing façades, structures, and buildings. The estimated percentages of reuse will be calculated with more granular information at Stage 3.

MEP Detailed Modelling: Detailed modelling. Following BREEAM requirements, another iteration of the LCA will be completed at Technical Design Stage. Detailed modelling of MEP will be undertaken at this stage at the latest.

B2 and B3 emissions: B2 and B3 emissions will be estimated and reported following the GLA guidance in the next iteration of the LCA (at the latest, Technical Detail Stage).

Built Environment Database: SMBL provides permission to submit assessment to the Built Environment Carbon Database

Operational modelling: The project is already committed to the use of the Design for Performance methodology during design development, with a target NABERS rating of 4.5* for the base building. The NABERS modelling will be used to report unregulated energy demand when the WLCA is updated post-construction

Additional result reporting

In addition to the figures quoted in this report, the following whole life-cycle carbon modules have been reported, in line with the new guidance and also calculation methodologies provided in the GLA WLCA Guidance (2022). These results are reported in the British Library GLA spreadsheet and are attached on the following page for reference.

The updates are as follows:

- B1 - Refrigerant impact has been added.
- B2 - As per the new GLA WLCA Guidance (2022), for module B2 emissions, a total figure of 10 kgCO2e/m2 gross internal area (GIA) may be used to cover all building element categories.
- B3 - For module B3 emissions, these may be estimated as 25 per cent of module B2, as per the RICS PS (item 3.5.3.3). In line with this, the GLA WLCA spreadsheet has been updated B2 (10 kgCO2e/m2 GIA) and B3 (2.5 kgCO2e/m2 GIA). These are divided into element categories as per the percentages provided in Table A2.1 of the new GLA WLCA Guidance (2022).
- B7 - Input as 5% of operational carbon as a conservative estimate based on assessment of other Arup LCA projects.

Refrigerants have been modelled based on the following quantities, which were provided by the MEP engineer:

Type	Quantity	Refrigerant	GWP (kgCO2e/kg)	Total refrigerant Charge (kg)	Annual leakage rate (%)	End of life recovery rate (%)
4-pipe ASHP (commercial)	5	R513A	631	2365	2	99
Air cooled chiller (commercial)	3	R513A	631	1290	2	99
4-pipe ASHP (library)	4	R513A	631	1248	2	99
Air cooled chiller (library)	1	R513A	631	480	2	99
DX Units	4	R410A	2088	18.9	4	98

The above figures are in line with the methodology of CIBSE TM65 – Embodied carbon in building services.

GLA WLC Results Spreadsheet: The British Library

GWP POTENTIAL FOR ALL LIFE-CYCLE MODULES ($kgCO_2e$) (See Note 1 below if you entered a reference study period in cell C12)		Sequestered / biogenic) carbon (negative value) ($kgCO_2e$)	Product stage ($kgCO_2e$)	Construction process stage ($kgCO_2e$)		Use stage ($kgCO_2e$)							End of Life (EoL) stage ($kgCO_2e$)				TOTAL Modules A-C $kgCO_2e$	Benefits & loads beyond the system boundary ($kgCO_2e$)
			Module A			Module B							Module C					Module D
Element category			[A1] to [A3]	[A4]	[A5]	[B1]	[B2]	[B3]	[B4]	[B5]	[B6]	[B7]	[C1]	[C2]	[C3]	[C4]		
0.1	Demolition: Toxic/Hazardous/ Contaminated Material Treatment																0 kg CO2e	
0.2	Major Demolition Works												304,133 kg CO2e				304,133 kg CO2e	
0.3	Temporary Support to Adjacent Structures																0 kg CO2e	
0.4	Specialist Ground Works																0 kg CO2e	
0.5	Temporary Diversion Works																0 kg CO2e	
1	**Substructure**	-41,664 kg CO2e	6,590,541 kg CO2e	471,910 kg CO2e	317,013 kg CO2e		169,292 kg CO2e	42,323 kg CO2e	0 kg CO2e					349,383 kg CO2e	73,243 kg CO2e	0 kg CO2e	7,972,042 kg CO2e	-1,759,128 kg CO2e
2.1	Superstructure: Frame	-307,912 kg CO2e	9,275,659 kg CO2e	247,498 kg CO2e	424,703 kg CO2e		320,764 kg CO2e	80,191 kg CO2e	0 kg CO2e					334,742 kg CO2e	333,899 kg CO2e	0 kg CO2e	10,709,544 kg CO2e	-3,240,416 kg CO2e
2.2	Superstructure: Upper Floors	-714,553 kg CO2e	5,104,429 kg CO2e	397,724 kg CO2e	253,712 kg CO2e		0 kg CO2e	0 kg CO2e	0 kg CO2e					238,506 kg CO2e	743,350 kg CO2e	0 kg CO2e	6,023,168 kg CO2e	-1,798,984 kg CO2e
2.3	Superstructure: Roof	-2,624 kg CO2e	1,254,146 kg CO2e	56,353 kg CO2e	50,633 kg CO2e		0 kg CO2e	0 kg CO2e	702,666 kg CO2e					30,499 kg CO2e	96,885 kg CO2e	1,252 kg CO2e	2,189,809 kg CO2e	-395,541 kg CO2e
2.4	Superstructure: Stairs and Ramps	-289 kg CO2e	44,721 kg CO2e	3,367 kg CO2e	2,143 kg CO2e		0 kg CO2e	0 kg CO2e	0 kg CO2e					2,182 kg CO2e	499 kg CO2e	0 kg CO2e	52,622 kg CO2e	-15,527 kg CO2e
2.5	Superstructure: External Walls	-666 kg CO2e	6,951,792 kg CO2e	87,605 kg CO2e	413,974 kg CO2e		151,472 kg CO2e	37,868 kg CO2e	6,979,603 kg CO2e					52,845 kg CO2e	56,466 kg CO2e	1,556 kg CO2e	14,732,514 kg CO2e	-8,019,034 kg CO2e
2.6	Superstructure: Windows and External Doors	0 kg CO2e	1,073,148 kg CO2e	15,899 kg CO2e	0 kg CO2e		0 kg CO2e	0 kg CO2e	1,099,848 kg CO2e					10,600 kg CO2e	58 kg CO2e	144 kg CO2e	2,199,697 kg CO2e	-5,787 kg CO2e
2.7	Superstructure: Internal Walls and Partitions	0 kg CO2e	2,364,162 kg CO2e	142,683 kg CO2e	99,359 kg CO2e		0 kg CO2e	0 kg CO2e	1,745,394 kg CO2e					323,181 kg CO2e	194,148 kg CO2e	2,410 kg CO2e	4,871,337 kg CO2e	0 kg CO2e
2.8	Superstructure: Internal Doors	0 kg CO2e	1,273,010 kg CO2e	76,829 kg CO2e	53,501 kg CO2e		0 kg CO2e	0 kg CO2e	0 kg CO2e					174,020 kg CO2e	104,541 kg CO2e	1,298 kg CO2e	1,683,200 kg CO2e	0 kg CO2e
3	**Finishes**	0 kg CO2e	6,061,953 kg CO2e	365,855 kg CO2e	254,767 kg CO2e		89,101 kg CO2e	22,275 kg CO2e	4,538,025 kg CO2e					3,619,703 kg CO2e	2,174,502 kg CO2e	26,991 kg CO2e	17,153,172 kg CO2e	0 kg CO2e
4	**Fittings, furnishings & equipment**	0 kg CO2e	1,616,521 kg CO2e	97,561 kg CO2e	67,938 kg CO2e		17,820 kg CO2e	4,455 kg CO2e	1,396,315 kg CO2e					1,284,229 kg CO2e	771,489 kg CO2e	9,576 kg CO2e	5,265,905 kg CO2e	0 kg CO2e
5	**Services (MEP)**	0 kg CO2e	10,103,255 kg CO2e	609,758 kg CO2e	424,612 kg CO2e	5,570,106 kg CO2e	124,741 kg CO2e	31,185 kg CO2e	6,516,138 kg CO2e		37,296,000 kg CO2e 60,774,000 kg CO2e	4,903,500 kg CO2e		4,238,602 kg CO2e	2,546,300 kg CO2e	31,606 kg CO2e	133,169,803 kg CO2e	0 kg CO2e
6	**Prefabricated Buildings and Building Units**																0 kg CO2e	
7	**Work to Existing Building**																0 kg CO2e	
8	**External works**	0 kg CO2e	64,484 kg CO2e	11,496 kg CO2e	3,155 kg CO2e		17,820 kg CO2e	4,455 kg CO2e	78,692 kg CO2e					2,429 kg CO2e	284 kg CO2e	0 kg CO2e	182,815 kg CO2e	-6,651 kg CO2e
Other site construction impacts or overall construction stage [A5] carbon emissions not specific to an individual building element category					0 kg CO2e												0 kg CO2e	
TOTAL kg CO_2e		**-1,067,708 kg CO2e**	**51,777,820 kg CO2e**	**2,584,537 kg CO2e**	**2,365,511 kg CO2e**	**5,570,106 kg CO2e**	**891,010 kg CO2e**	**222,753 kg CO2e**	**23,056,681 kg CO2e**	**0 kg CO2e**	**98,070,000 kg CO2e**	**4,903,500 kg CO2e**	**304,133 kg CO2e**	**10,660,921 kg CO2e**	**7,095,664 kg CO2e**	**74,833 kg CO2e**	**206,509,761 kg CO2e**	**-15,241,068 kg CO2e**
TOTAL - kg CO_2e/m^2 GIA		**-12 kg CO2e/m2 GIA**	**581 kg CO2e/m2 GIA**	**29 kg CO2e/m2 GIA**	**27 kg CO2e/m2 GIA**	**63 kg CO2e/m2 GIA**	**10 kg CO2e/m2 GIA**	**3 kg CO2e/m2 GIA**	**259 kg CO2e/m2 GIA**	**0 kg CO2e/m2 GIA**	**1,101 kg CO2e/m2 GIA**	**55 kg CO2e/m2 GIA**	**3 kg CO2e/m2 GIA**	**120 kg CO2e/m2 GIA**	**80 kg CO2e/m2 GIA**	**1 kg CO2e/m2 GIA**	**2,318 kg CO2e/m2 GIA**	**-171 kg CO2e/m2 GIA**

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