LONDON TUNNELS

The London Tunnels

35. Whole Life-Cycle Carbon Assessment

PROJECT NO. 70087403
REF NO. TLT-WSP-XX-XX-RP-ES-00003

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The London Tunnels Limited

THE LONDON TUNNELS

Whole Life Carbon Assessment

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EXECUTIVE SUMMARY

WSP has been appointed by The London Tunnels PLC to carry out a Whole Life Carbon Assessment for The London Tunnels in the City of London & the London Borough of Camden. The assessment was carried out in accordance with the GLA's Whole Life Carbon Assessment Methodology updated in March 2022.

This Whole Life Carbon (WLC) Assessment Report has been prepared by WSP and is submitted in support of a full planning application in relation to The London Tunnels (the "Site") on behalf of The London Tunnels PLC ("The Applicant"). The planning application is for *a change of use of existing deep level tunnels (Sui Generis) to visitor and cultural attraction, including bar (F1); demolition and reconstruction of existing building at 38-39 Furnival Street; redevelopment of 40-41 Furnival Street, for the principle visitor attraction pedestrian entrance at ground floor, with retail at first and second floor levels and ancillary offices at third and fourth levels and excavation of additional basement levels; creation of new, pedestrian entrance at 31-33 High Holborn, to provide secondary visitor attraction entrance (including principle bar entrance); provision of ancillary cycle parking, substation, servicing and plant, and other associated works. (the "Proposed Development").*

Three scenarios have been considered to include for current design development and future potential scenarios that may be included in the CAT B design. These are as follows:

- **Low Scenario:** the baseline-low case scenario represents the base building CAT A design where the building operates with anticipated occupancy and opening hours but there is no energy intensive audio-visual equipment installed.
- **Medium Scenario**: For the medium Scenario, the AV system is assumed to be mostly projectors with some screens, equivalent to roughly 50% AV coverage of the high scenario. This scenario lines up with the Medium Scenario in the Be Seen energy analysis.
- **High Scenario**: the high scenario is based on anticipated occupancy and opening hours with a higher proportion of the Tunnels containing AV equipment. The AV system in this case is assumed to be mostly LED screens with some projectors. This scenario lines up with the High and Worst Scenario in the Be Seen energy analysis.

The Whole Life Carbon for these three scenarios have been considered and is reported in

Table 1.

Table 1 – The London Tunnels Whole Life Carbon Results

TOTAL kg CO_2e/m^2 GIA	Module A1-A5 (Excluding Sequestered Carbon)	Modules B-C (Excluding B6 & B7)	Modules A-C (Excluding B6 & B7; Including Sequestered Carbon)
Low Scenario	581	380	961
Medium Scenario	745	914	1,652
High Scenario	906	1,427	2,333
GLA Benchmark	<850	<200	<1050
GLA Aspirational Benchmark	<550	<140	<690

As observed by

Table 1 the low scenario would result in an upfront figure of 581 kg CO_2e/m^2 which is above the GLA aspirational benchmark of 550 kg CO_2e/m^2, the whole life carbon for this scenario would also result in the GLA benchmark being met although the aspirational benchmark exceeded. The medium scenario has been proposed throughout this report, the Whole Life Carbon for the medium scenario is higher than the GLA WLC benchmark of <1,050 kg CO_2e/m^2 for retail buildings. Modules A1-A5 result in 745 kg CO_2e/m^2 which is lower than the GLA upfront benchmark of <850 kg CO_2e/m^2. Modules B & C are estimated to produce 880 kg CO_2e/m^2 which is higher than the GLA benchmark whilst, although not included in the WLC figure, B6 & B7 are estimated to produce 11,583 t CO_2e. The high scenario would result in 906 kg CO_2e/m^2 for upfront carbon and 2,333 kg CO_2e/m^2 for whole life carbon which would exceed the GLA benchmark quite significantly, particularly for whole life carbon.

The screens and the projectors are the highest contributors to both upfront and whole life carbon emissions. As can be observed, modules B-C are significant contributors to the carbon, consisting predominantly of lifecycle stage B4 (replacement) accounting for approximately 52% of WLC emissions for the medium scenario, with A1-A3 materials being the second largest contributor to this. However, the efficient use of materials in addition to designing out waste throughout the design and construction process has led to significant reductions in embodied emissions which can be observed throughout this report. Various scenarios have been investigated as outlined above and the impact of screens has been acknowledged by the design team and will be taken into consideration when developing the CAT B design through product selection, compensating measures in other areas and optimised AV design.

Although The London Tunnels has been compared against the GLA retail benchmarks (as this is the most applicable GLA benchmark available), this comparison is not necessarily the most appropriate due to the bespoke nature of the project with proposed uses as a museum & event space. As a result, TLT has also been compared to other retention focused cultural developments in London such as the Museum of London and Liverpool Everyman Theatre, comparing both kg CO_2e/m^2 and kg CO_2e/visitor.

When the calculated WLC is divided by the expected capacity over the lifetime of the development the whole life carbon per visitor is significantly lower within The London Tunnels than both the MOL and the Liverpool Everyman.

A full summary of the results for the medium scenario is provided in the figures and charts presented throughout this report.

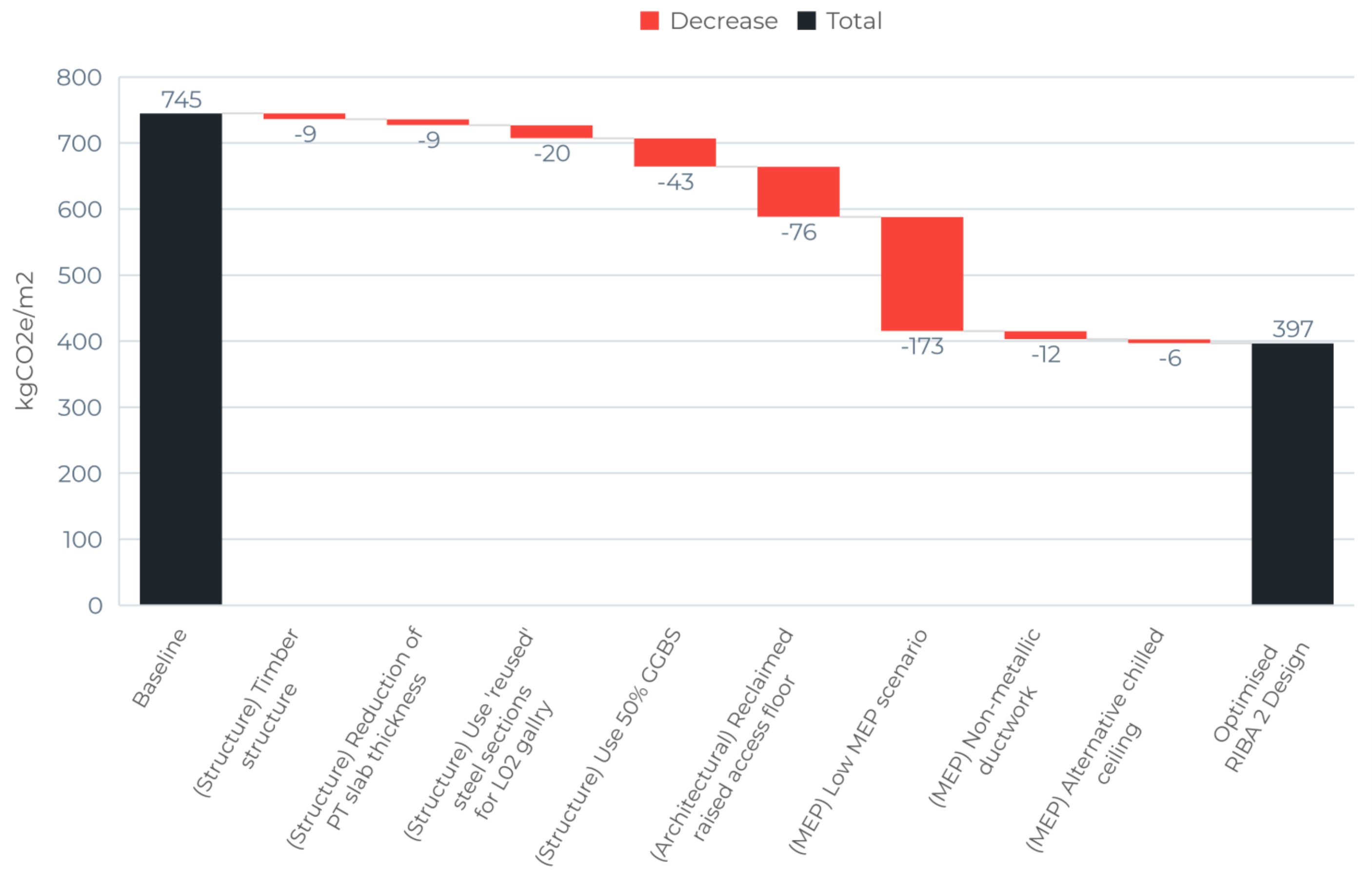

Figure 1 – Further Carbon Saving Opportunities (A1-A5)

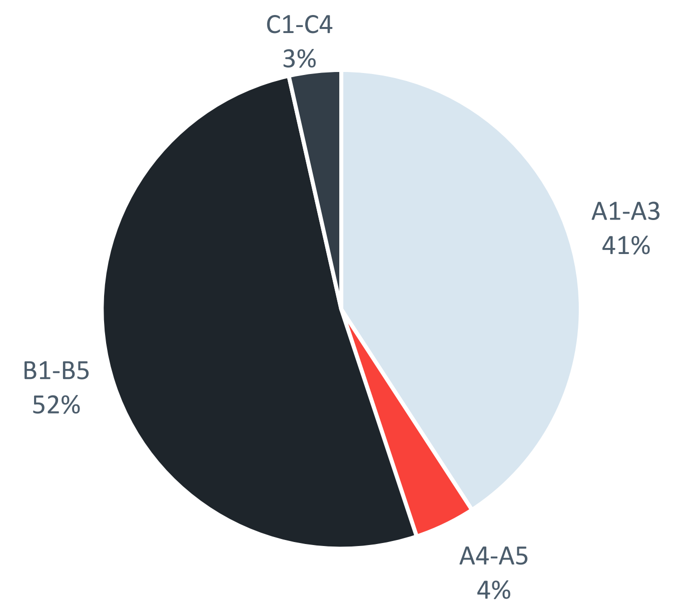

Figure 2 – Total kgCO$_2$e/m^2- Lifecycle Stages (Excluding Sequestration)

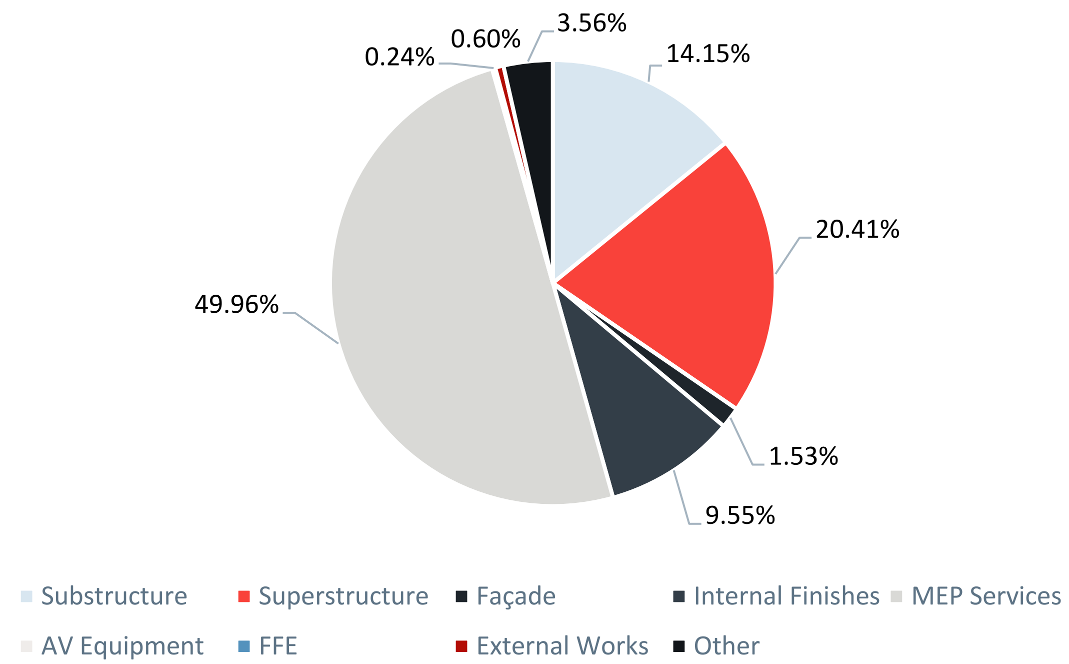

Figure 3 – Upfront Carbon (A1-A5)Total kgCO$_2$e/m^2-Building Elements

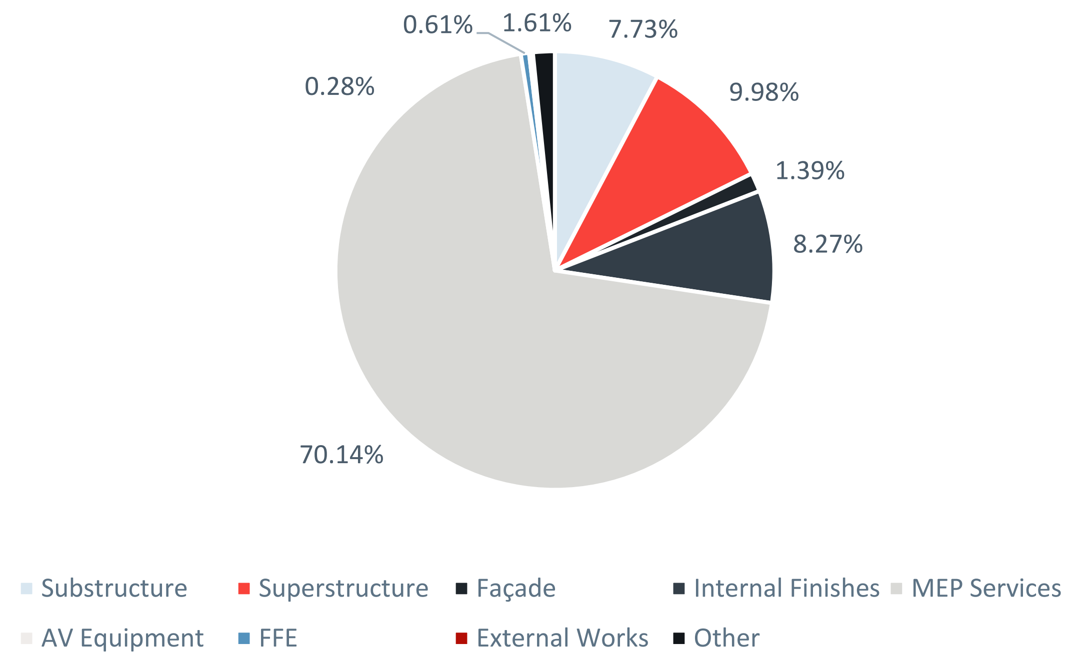

Figure 4 – Whole Life Carbon Total kgCO$_2$e/m^2-Building Elements TBU

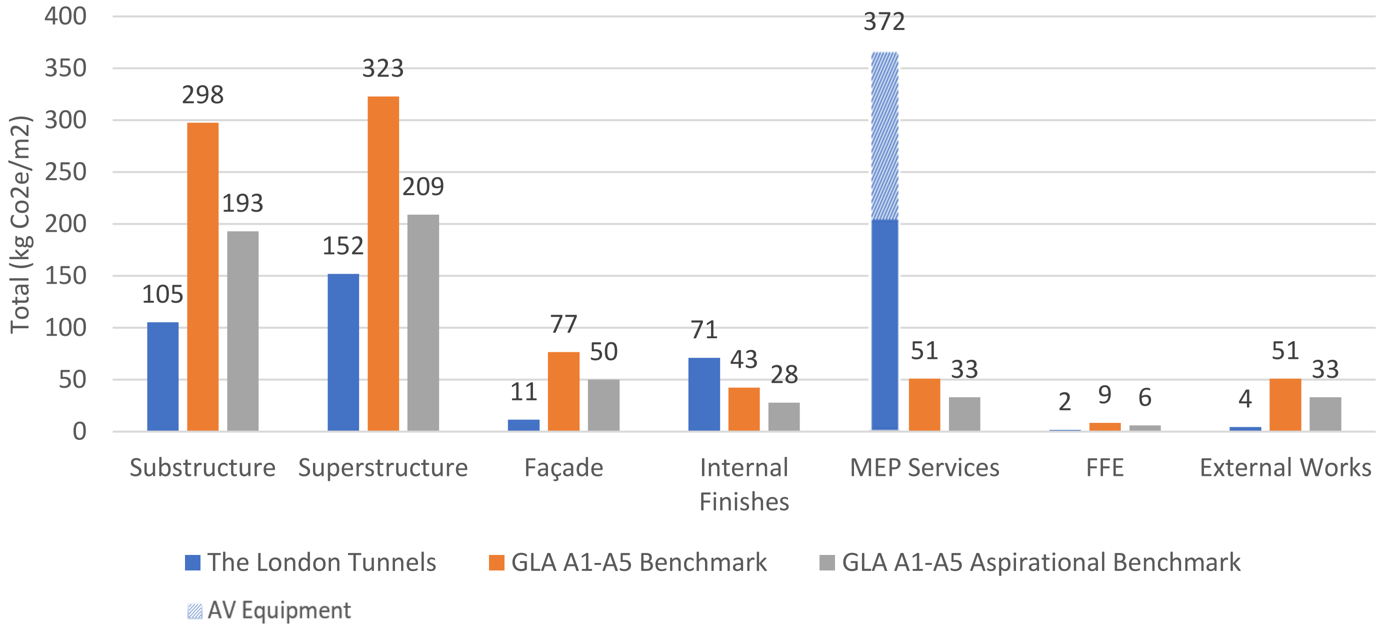

Figure 5 – Upfront Carbon (A1-A5) kgCO_2e/m^2 for The London Tunnels to GLA Benchmarks for a Typical Retail Development

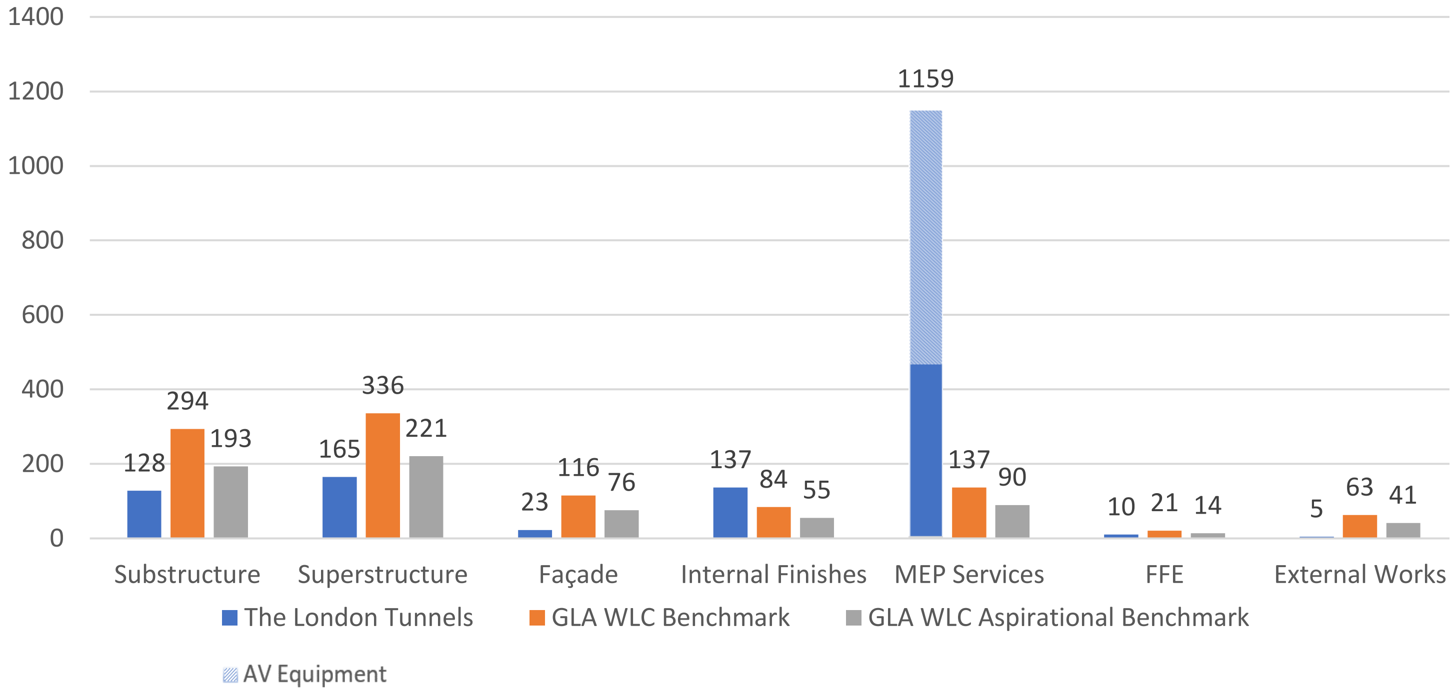

Figure 6 – Whole Life Total kgCO_2e/m^2 for The London Tunnels to GLA Benchmarks for a Typical Retail Development(Excluding B6 & B7)

1 BACKGROUND

Climate change is one of the most important environmental challenges of our time. Global warming is becoming an increasing issue resulting from the release anthropogenic (man-made) greenhouse gas emissions into the atmosphere, these are known as carbon emissions. These emissions may have severe adverse environmental, economic, and social implications globally if temperatures continue to increase. International treaties and initiatives such as the Paris Agreement, adopted in 2015, aim to limit temperature rise to 1.5°C by reducing carbon emissions which are also associated with natural resource depletion and pollution. To achieve this the UK a has made a commitment to bring all their greenhouse gas emissions to net zero by 2050. The scale of the challenge to achieve this aim can be seen in Figure 1-1.

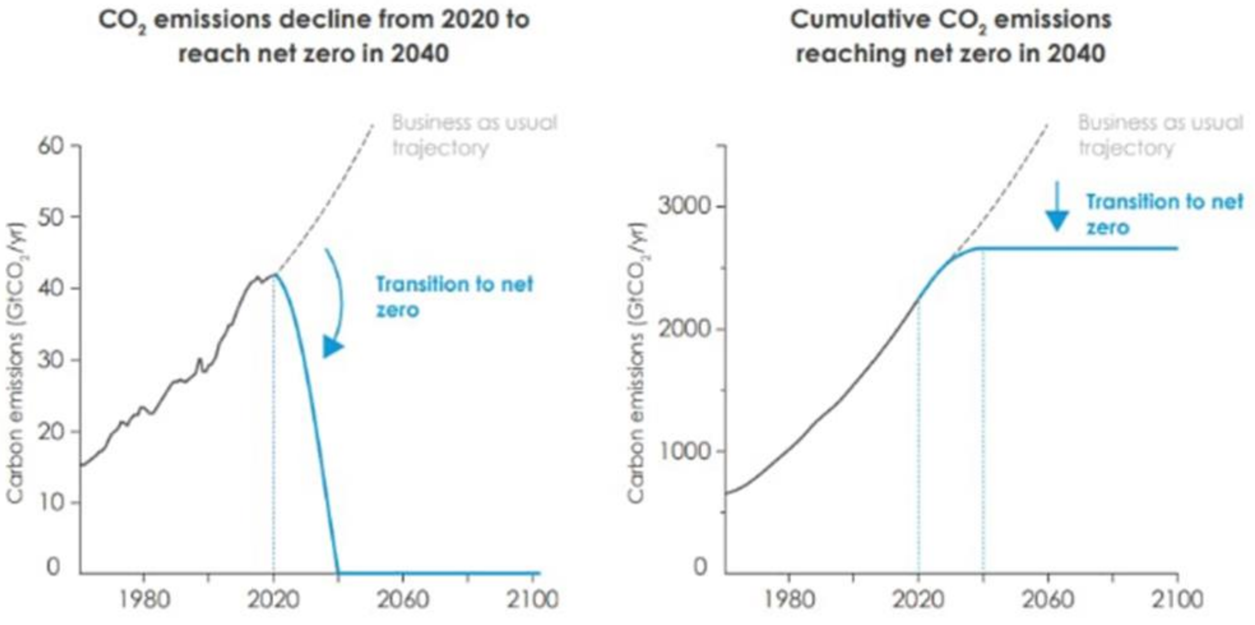

Figure 1-1 – Scale of Carbon Emissions Reductions to Limit to to 1. 5ºC (LETI CEDG p15)

Large quantities of carbon emissions arise from the built environment and are attributable not only to the use of built assets (operational emissions) but also to their construction (embodied emissions). Operational emissions are attributable to the everyday running of a building whereas embodied emissions result from the production, procurement and installation of the building's materials and components (construction). Embodied emissions also include the lifetime emissions from maintenance repair, replacement, demolition, and disposal.

Operational emissions in the built environment are being addressed via building regulations reduction targets (Part L), local authority planning requirements, and sustainability assessment rating schemes such as BREEAM, LEED, Whole Life Carbon/Lifecycle Assessments etc. Embodied carbon emissions constitute approximately half of a building's whole life cycle impact and have not yet been fully addressed. To understand the project's total carbon impact, it is necessary to assess the operational and embodied emissions over the whole life of the building. The consideration of both the operational, as well as embodied emissions over the projects expected life cycle constitutes a whole life approach.

Adopting a whole life approach means that the best opportunities for reducing lifetime emissions and avoidance of any unintended carbon emissions can be identified and provide the true picture of a building's environmental impact (of which carbon is just one of its factors) rather than focusing on operational emissions alone. For example, the quantity of embodied carbon for installing triple glazing rather than double can be larger than the operational benefit resulting from the additional pane. Consequently, whole life carbon must be well integrated into building design to achieve a lower carbon future. The principal benefits of conducting a WLC Assessment include:

- Identifying and accounting for emission sources which is critical to achieve carbon reduction goals;
- Achievement of resource efficiency and cost savings through the re-use of existing materials and the minimisation of waste through design principles;
- Identification of the carbon benefits of using recycled material in addition to the benefits of designing for future recycling and reuse, reducing waste, and supporting the circular economy;
- Finding optimal, holistic, solutions for the development over its lifetime by considering both operational and embodied emissions;
- Improving lifetime resource efficiency and costs by identifying the impact of maintenance, repair, and replacement of components over the building's lifecycle, contributing to the future proofing of the asset's value;
- Encouragement of local sourcing of materials and short supply chains will consequently have positive carbon, social, and local economic benefits; and
- Encouraging flexible design and durable construction, contributing to increased longevity and decreased obsolescence of buildings which also helps to reduce carbon emissions associated with their demolition and new construction.

2 INTRODUCTION

This WLC Assessment Report has been prepared by WSP and is submitted in support of a full planning application in relation to The London Tunnels (the "Site") on behalf of The London Tunnels PLC ("The Applicant").

The purpose of the WLC report is to quantitatively assess the Development in terms of carbon emissions. This promotes an understanding of resource efficiency, illustrates the benefits of specifying end of life and encourages durable and flexible design. A WLC assessment is encouraged by the GLA at the following planning stages:

- Pre-application;
- Planning application submission (RIBA Stage 2/3); and
- Post construction (RIBA Stage 5/6, approximately 3 months post-completion).

2.1 STATEMENT PURPOSE AND STRUCTURE

The purpose of this statement is to demonstrate how the development has and will continue to incorporate whole life carbon principles of reduction through design and construction activities, into the lifecycle of the assets and its componentry.

This strategy is in alignment with principles and policies on Whole Life Carbon Assessments as set out by various organisations such as the GLA and the Royal Institute of Chartered Surveyors (RICS). The structure of this strategy is as follows:

- **Chapter 1:** provides some background on climate change and the importance of whole life carbon on a global scale.
- **Chapter 2:** the introduction and provides an overview the development, existing buildings, planning context, whole life carbon optioneering and key design choices.
- **Chapter 3:** approach, methodology, targets & benchmarks.
- **Chapter 4:** assumptions.
- **Chapter 5** Covers third party verification.
- **Chapter 6:** summarises results.
- **Chapter 7:** looks into future opportunities to further reduce carbon emissions.
- **Chapter 8:** is the conclusion and summarizes the key points discussed in the document.

2.2 DEVELOPMENT DESCRIPTION

The works proposed involve *the change of use of existing deep level tunnels (Sui Generis) to visitor and cultural attraction, including bar (F1); demolition and reconstruction of existing building at 38-39 Furnival Street; redevelopment of 40-41 Furnival Street, for the principle visitor attraction pedestrian entrance at ground floor, with retail at first and second floor levels and ancillary offices at third and fourth levels and excavation of additional basement levels; creation of new, pedestrian entrance at 31-33 High Holborn, to provide secondary visitor attraction entrance (including principle bar entrance); provision of ancillary cycle parking, substation, servicing and plant, and other associated works.*

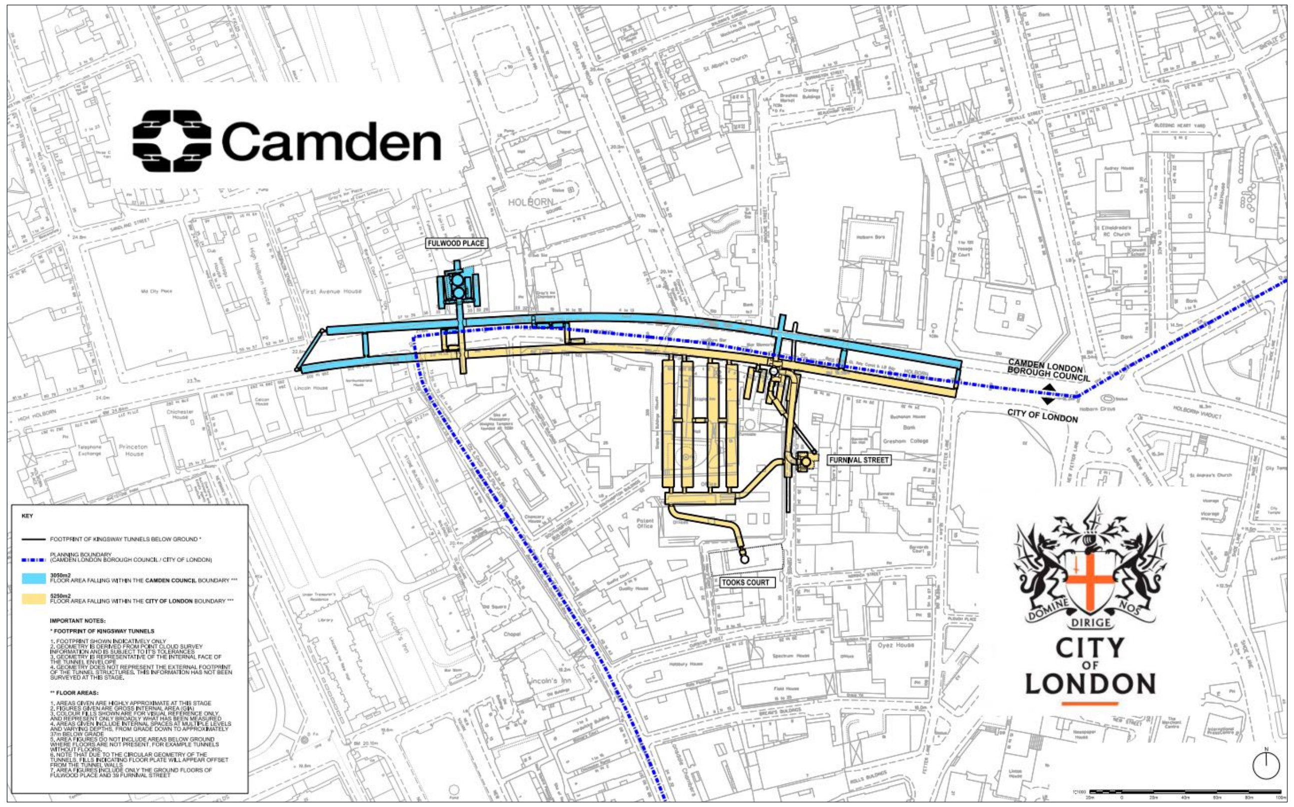

Figure 2-1 – The Tunnels Site and Entrances

The Kingsway Tunnels are located 40 meters below ground and sit directly below High Holborn Street with an area of 8,454 m^2. The site is located across two planning authorities as shown in Figure 2-1. 3,050 m^2 of floorspace will be located in the CoL and 5,250 m^2 in LBC. The Tunnels will have two main entrances – 31-33 High Holborn, in the Borough of Camden (Figure 2-2), and 38-39 and 40-41 Furnival Street, in the City of London (Figure 2-3).

Figure 2-2 – Entrance 31-33 High Holborn and the Proposed Façade Amendments

Figure 2-3 –Proposed Entrance 39-40 at Furnival Street

The Client is looking to explore potential opportunities for refurbishment or redevelopment of the site, with the intention of:

- Creating a world-class landmark.
- Develop a unique immersive experience.
- Provide added value to the city.
- Preserve the historic value of the Kingsway Tunnels.
- Provide gift shops and bar.
- The office and retail/bar spaces are targeting a BREEAM Rating of “Very Good”.

Figure 2-4 shows an anticipated visitor experience within the proposed development. It is anticipated that 2 million people per year will visit the development.

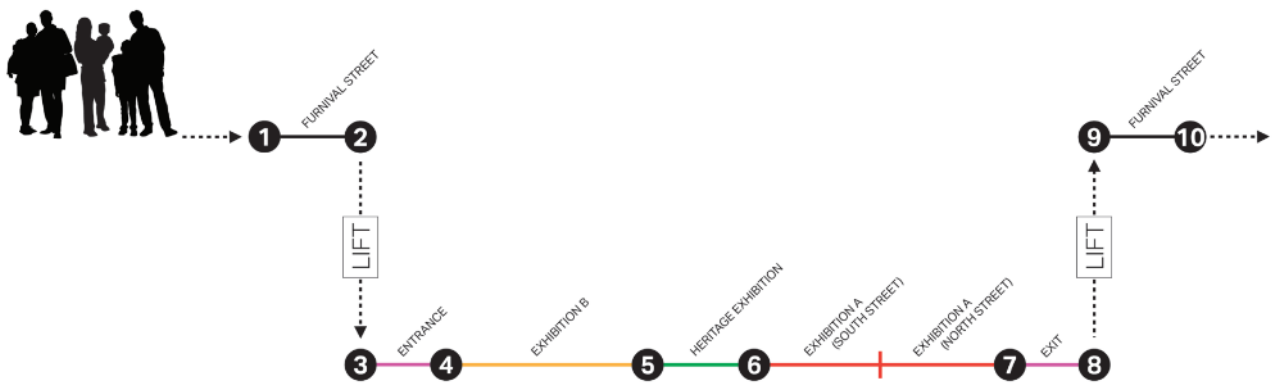

Figure 2-4 – Visitor Experience within the Proposed Development

The Proposed Development would make a significant contribution to London’s cultural offer, maintain an important historical asset, and generally increase footfall within the City of London.

2.2.1 EXISTING SITE

The Proposed Development considers the heritage context and the existing built character of the site, as a result this section summarised the characteristics of the existing site including the tunnel, Furnival Street buildings and 31-33 High Holborn.

The Tunnels

The Tunnels were built during the early 1940s. BT (British Telecom) took ownership after the war from the Greater London Council, converting them to telecommunication exchange.

Figure 2-5 - Diagram Highlighting the London Tunnels under Holborn

The Kingsway Tunnels are subdivided in different elements:

- The Streets – these are thought to be part of the original construction. They are 5.2m in diameter and its structures varies between cast iron rings and precast concrete rings. A closer inspection suggest that part of the structure was altered in the early 50’s. The current finish floor level is provided by a concrete slab supported by a secondary steel frame. There is limited information about the existing build-up below the finish floor structure.
- The Avenues - the avenues are part of the second stage of construction and believed to be part of the works undertaken by BT when they took possession of the tunnels. As per the streets, the structure varies between cast iron ring panels and precast concrete panels. The finish floor levels are similar as per the streets.
- The “Dog Leg”- the secondary Tunnels connecting Furnival Street shaft to a construction shaft is located half way between ground level and Tunnels level. This appears to be part of the second construction stage and built as a construction tunnel. This Tunnels connects Furnival Street shaft to the disused construction shaft 2.

- The Ventilation Tunnels - there is a secondary network of smaller Tunnels providing ventilation routes between adjacent tunnels. These are too narrow for public use but provide opportunities for services distribution.
- The Disused shafts - the Tunnels include a number of shafts and vertical connections that have been blocked or made unusable due to more recent developments. These include:
  - Chancery Lane tube station connection shaft
  - Took's Court Shaft
  - Staples Inn shaft
- The Access Shafts - these include both shafts at 31-33 High Holborn and the Goods Shaft at Furnival Street. The Scheme relies in these connections to provide safe access and evacuation to the tunnels.

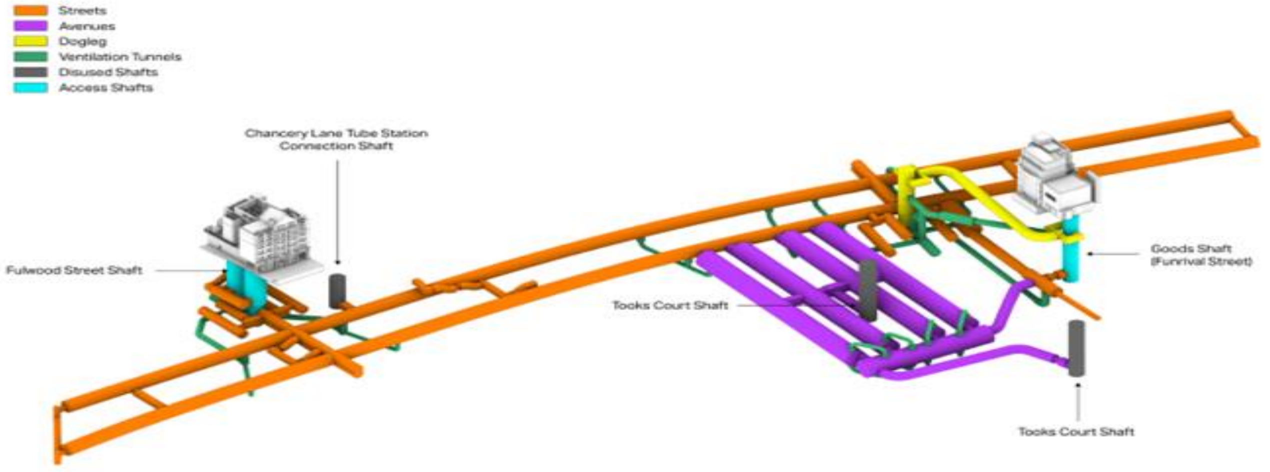

Figure 2-6 – The London Tunnels Structure

38-39 and 40-41 Furnival Street

The existing building on site at 38-39 Furnival Street serves as one of the two entrances to the tunnels. It was reconstructed in the late 1940s following substantial damage caused by a V1 rocket explosion across the street. The building houses a lift access shaft and a ventilation shaft connected to the 'Dog Leg' tunnel. While it is not currently listed as a historical site, it has a distinctive concrete louver on the facade which is going to be retained. Demolition of this building is planned to facilitate shaft expansion and visitor access to the tunnels, but efforts will be made to preserve its architectural character in terms of geometry, use, and materiality. Due to the limitations of various elements of 38-39 Furnival Street, this building is proposed to be demolished and rebuilt.

The 40-41 Furnival Street property comprises of a purpose-built office building arranged over basement, ground and five upper floors, dating from around 1990. The building is of steel framed construction with part brick, part glazed elevations under a flat asphalt roof. The windows are double glazed with powder coated aluminium frames. The property underwent a refurbishment in 2016. The current building consists of 7 levels with a GIA of approximately 1300m2.

Figure 2-7 – Existing 39 Furnival Street

Figure 2-8 – Existing 40-41 Furnival Street

31-33 High Holborn

31-33 High Holborn is assumed to be built in approximately 1885 and formed the original entrance to Chancery Lane Underground Station. The entrance was moved to a new place in 1930s and the old entrance became redundant until the 1940s where the Government ordered the construction of deep shelters linked to existing tube stations. According to DAS document there are two levels in this building one of which is the basement. Currently the building does not have a direct frontage to the main street, and the only entrance is through a narrow alley from the back courtyard. The current entrance has limited space and is unlikely to accommodate the desired number of visitors.

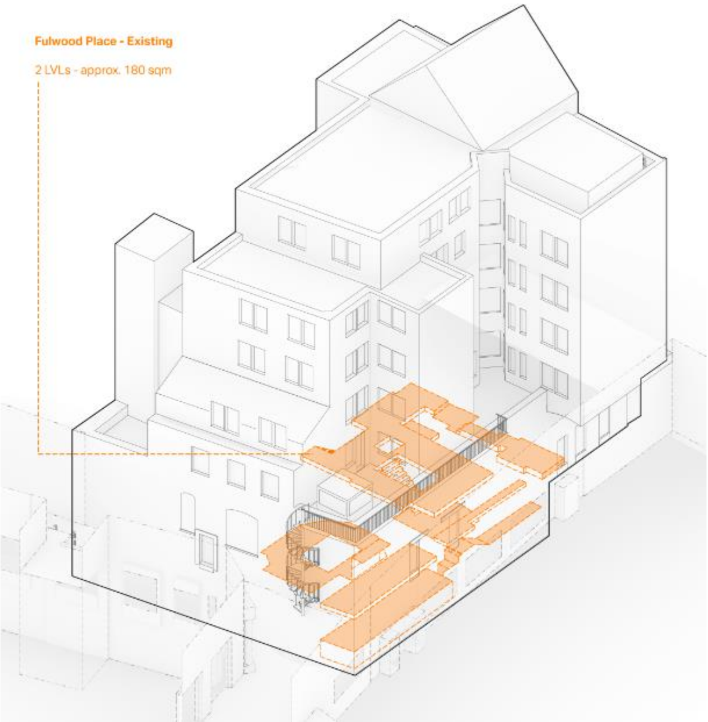

Figure 2-9 – Existing 31-33 High Holborn entrance (according to the point-cloud and the 3D scan)

Key Development Constraints

The Proposed Development is influenced by the following below and above ground constraints (extract from Structural Report):

Party walls

There are existing buildings all around the site. The Party Wall Agreements need to be sought in due course as a legal requirement and to mitigate the risk on the project.

Rights of light

The building from has been designed to fit within the rights of light envelope. This has resulted in the need for walking and raking columns to transfer structure and aligned with the envelope.

Existing Basement, Shafts and Tunnels

- The existing 38-39 Furnival Street needs to be rebuilt to allow access to the shaft
- The existing shaft is currently not suitable for access to the Tunnels so needs upgrading and enlarging to meet regulations
- 40-41 Furnival Street was built in the 1980s and does not currently have sufficient floor to ceiling height to accommodate MEP plant requirements

For more detail refer to the Structural Report (reference TLT-WSP-ZZ-RP-ST-00001.

2.3 POLICY CONTEXT REVIEW

The Whole Life Carbon Assessment has been produced in response to the planning requirement and guidelines outlined in the following table:

Table 2-1 – London Plan (March 2021) - Relevant to WLC

New London Plan (March 2021)	
Policy SI2 Minimising greenhouse gas emissions	A. Major development should be net zero-carbon. This means reducing greenhouse gas emissions in operation and minimising both annual and peak energy demand in accordance with the following energy hierarchy: 1. Be lean: use less energy and manage demand during operation. 2. Be clean: exploit local energy resources (such as secondary heat) and supply energy efficiently and cleanly. 3. Be green: maximise opportunities for renewable energy by producing, storing, and using renewable energy on-site. 4. Be seen: monitor, verify and report on energy performance. B. Major development proposals should calculate and minimise carbon emissions from any other part of the development, including plant or equipment, that are not covered by Building Regulations, i.e., unregulated emissions. C. Development proposals referable to the mayor should calculate whole life-cycle carbon emissions through a nationally recognised WLC Assessment and demonstrate actions taken to reduce life-cycle carbon emissions.

2.3.1 CITY OF LONDON LOCAL PLAN

The London Tunnels will support the COL's local plan by providing space that is flexible & adaptable, promoting visitation of the Proposed Development within the City whilst at the same time preserving the natural history of the tunnels.

2.3.2 LONDON BOROUGH OF CAMDEN LOCAL PLAN

The London Tunnels will support the London Borough of Camden's local plan through the support of economic development and providing employment premises and sites whilst at the same time encouraging tourism and retaining the heritage of the tunnels.

2.3.3 CITY OF LONDON WHOLE LIFE CARBON OPTIONEERING PLANNING ADVICE NOTE (MARCH 2023)

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

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

- Developers to calculate and report the WLC of realistic and feasible options at pre-application where there are existing buildings on site;
- The emissions associated with a minor refurbishment, major refurbishment, significant refurbishment & extension, and new-build options should be compared – compelling clients and design teams to look for opportunities to minimise demolition;

- A WLC reporting dashboard to increase consistency of supporting carbon documents across pre-app and planning application submissions;
- Scope and assumptions across all options to be consistent and presented in a transparent way, without bias; and
- An independent third-party verification to be carried out on all optioneering assessments as a quality assurance mechanism.

2.3.4 HERITAGE CONSIDERATIONS

The Kingsway Tunnels originated as the Chancery Lane deep-level shelter; one of the eight deep-level air raid shelters constructed by the British Government during the Second World War to provide protection to Londoners during the Blitz. Immediately after the war, the east-west Tunnels were briefly used for storage by the Public Records Office (now the National Archives). The former bunks that lined the corridors of the Tunnels were converted to create 80,000ft (24,000m) of shelving.

In 1949 the Chancery Lane shelter was given over by the General Post Office to be converted for use as an underground telephone trunk exchange. The Tunnels system was extended through the construction of four large-diameter lateral (north-south) tubes under Staple Inn to accommodate automatic switching equipment. From c.1980 Kingsway ceased to be used as a trunk exchange and the complex was used for other purposes by British Telecom. However, in the early 1980s the Tunnels were subject to a phased closure after blue asbestos was found. By 1995 only the main distribution frame was still in service. In October 2008, BT announced that the Tunnels were for sale.

This development Scheme provides an opportunity to rejuvenate these historic Tunnels and enable the public to experience this unique piece of British heritage for the first time. Further, bringing a major tourist attraction to this area will create additional commercial opportunities for local businesses. All 3 options being considered include the retention of 100% of the Tunnels network, which make up over 90% of the total Scheme.

2.4 WHOLE LIFE CARBON OPTIONEERING STUDY

In line with the *City of London's WLC PAN*, a WLC options appraisal study was carried out at early concept stages to quantify the relative carbon impact of different proposals. This included discipline input. As the Tunnels and 31-33 High Holborn will largely be retained and the Tunnels network falls within the City of London Boundary they are proposed to be excluded from the optioneering assessment due to

- Over 90% of the Scheme and the entirety of Tunnels network will be retained.
- The Tunnels network has a total length of over a mile, with approximately 60% in the City of London.
- The Tunnels works would remain consistent across the options presented.
- This option appraisal therefore concentrates on those parts that do change in the different strategies.

The optioneering assessment focuses 38-39 and 40-41 Furnival Street which sit within the City of London boundary. In order to satisfy the City of London Carbon Options Guidance PAN –various degrees of refurbishment have been considered for the buildings at Furnival Street.

- Various levels of retention for 40-41 Furnival Street have been considered.
- Retention of 38-39 Furnival Street has been investigated and shown to be unfeasible. The building's demolition is necessary for safe construction and access to enable the London Tunnels project. Retention/reclamation of historic features are considered.
- 38-39 and 40-41 Furnival Street are proposed to be assessed in one Optioneering Study. The results of each can be observed in the optioneering report. A summary of the report is seen below.

2.4.1 OPTIONS CONSIDERED

Major Refurbishment (Option 1)

Option 1 looks to undertake the minimum necessary works to the development in order for the building to allow access to the Tunnels below through a major preservation of 40-41 Furnival Street with a rebuild of 38-39 Furnival Street.

38-39 Furnival Street: Building demolished. New three-level basement constructed; shaft enlarged down to Tunnels entrance; superstructure rebuilt with one additional floor.

40-41 Furnival Street: All substructure and majority of superstructure retained. Openings created in level 5 slab to allow sufficient height for MEP. One additional floor added. Retained slabs, columns and possibly foundations strengthened to accommodate openings and increased loading from new floors and building services plant.

Full Replacement and upgrade of existing façade systems in addition to new MEP plant strategy, internal finishes & FFE.

Major Refurbishment with Extension (Option 2)

Option 2 considers an extension to the existing structure of 40-41 Furnival Street and a complete rebuild of 38-39 Furnival Street to improve on space utilisation.

38-39 Furnival Street: Building demolished and reconstructed as option 1.

40-41 Furnival Street: Substructure and ground to 3rd floors retained. Retained slabs, columns and possibly foundations strengthened to accommodate increased loading from new floors and building services plant. Partial demolition of superstructure (top 3 levels). Replacement structure has no additional floors but greater height and more efficient space for MEP plant.

Full Replacement and upgrade of existing façade systems in addition to new MEP plant strategy, internal finishes & FFE.

New build (Option 3)

The proposed Scheme is a new build, the detailed whole life carbon emissions associated with this option are defined in this report. Option 3 looks to rebuild both 40-41 and 38-39 Furnival Street to improve on space utilisation, access, and future maintenance of MEP equipment compared with Options 1 and 2.

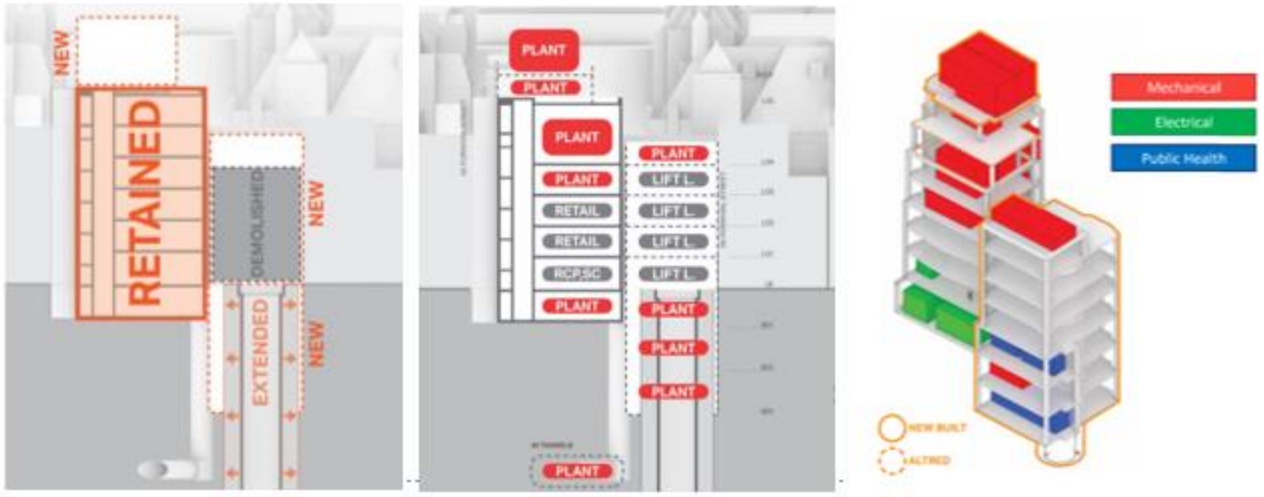

Figure 2-10 – Option 1 - Major Refurbishment

Figure 2-11 – Option 2 - Major Refurbishment with Extension

Figure 2-12 – Option 3 – New Build

2.4.2 RESULTS

The upfront carbon (A1-A5) is estimated to produce 666 kg CO_2e/m^2 for Option 1, 616 kg CO_2e/m^2 for Option 2 and 818 kg CO_2e/m^2 for Option 3. The Whole Life Carbon for Option 1 is 1118 kg CO_2e/m^2, 1077 kg CO_2e/m^2 for Option 2 and 1271 kg $CO2e/m^2$ for Option 3 (modules A-C, excluding demolition, B6 & B7; including sequestered carbon), see summary in Table 2-2

Table 2-2 – Embodied Carbon Summary of Options (kg CO_2e/m^2)

	Module A1-A5 (Excluding Sequestered Carbon)	Modules A-C (Excluding B6 & B7; Including Sequestered Carbon)
Option 1	666	1,130
Option 2	616	1,077
Option 3	818	1,271

The results clearly indicate that Options 1, 2 and 3 achieve comparable levels of upfront and whole life carbon performance, with the refurbishment options showing minor savings compared to the new-build option. This is due to the inefficiencies in areas and considerable structural works associated with the major refurbishment options.

Considering absolute emissions, Options 1 and 2 are estimated to achieve 6% and 8% less emissions than Option 3. This is largely due to the fact that the refurbishment options have lower GIAs than the New Build (Option 3).

All options have been assumed to have the same structural repair and maintenance embodied carbon. Whilst a value cannot be accurately estimated based on available data – it is noted that options 1 and 2, which retain the significant parts of the 40-41 Furnival Street structural frame, are likely to require higher levels of intervention throughout the in-use period.

2.5 RIBA STAGE 2 DESIGN STRATEGY

This section of the report sets out carbon savings that have been considered during the RIBA Stage 2 design and proposed for inclusion in the Proposed Development. Where feasible these have been incorporated into the Whole Life Carbon Assessment. Key items from each design discipline are considered below.

2.5.1 STRUCTURAL ENGINEERING

2.5.1.1 Existing Structure

40-41 Furnival Street

WSP's understanding of the structure at 40-41 Furnival Street is as follows:

- Six storey office building with single storey basement. The roof (6th floor) includes a lift overrun, MEP enclosure and vaulted roof.
- The architectural drawings associated with the original planning application indicate a reinforced concrete frame, floor slabs and core. This is corroborated by a statement from a 2015 planning application (15/01240) Design & Access statement that defined the structure as a 'reinforced concrete frame'. The assumption is also supported by findings from a WSP visual site inspection.
- Based on planning application drawings, assumptions have been made regarding the structural frame. These were used in developing structural options for the City of London planning stage Whole Life Carbon Optioneering.

38-39 Furnival Street

No record drawings are available for the current building at 38-39 Furnival Street. Following visual inspection and review of the point cloud survey, WSP's understanding of the structure at 38-39 Furnival Street is as follows:

- Front elevation includes a masonry façade framed around a large concrete louvred opening.
- Flat roof formed at approximately a 4th floor level.
- Matterport point cloud survey indicates that a portion of the floor plate is open at 1st and 2nd floor. The soffit of a slab at 3rd floor level can be seen.
- Partitions and existing openings infilled with blockwork.
- The soffit of a beam over the entrance and the slab at 3rd floor show the imprints of slatted formwork; indicating reinforced concrete construction.

Figure 2-13 – Existing Site Showing 40-41 Furnival Street (Left) and 38-39 Furnival Street (Right)

31-33 High Holborn

Record structural drawings indicate that the building frame above first floor is load bearing masonry walls and piers. The floors are formed from steel beams spanning approximately 10-11m between masonry. The floor deck is comprised of a filler joist concrete slab construction, which spans between steel beams. The structure below first floor is unknown and subject to further survey.

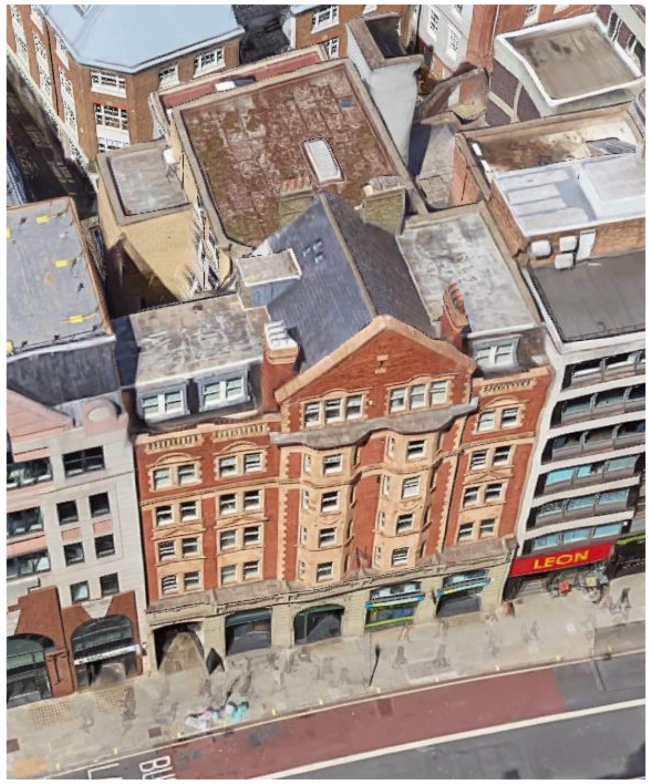

Figure 2-14 – Existing Site at 31-33 High Holborn

2.5.1.2 38-39 and 40-41 Furnival Street New Structure

A variety of structural systems have been considered through the course of this design phase. Each system has been evaluated with respect to the project brief, architectural design intent, programme, sustainability, and cost.

2.5.1.3 Design Opportunities

The design of the structural systems has been developed embracing the following principles:

- Develop the concept to provide flexible space that can extend the life of the building and enhance the building users' experience.
- Design structures economically to minimise embodied carbon
- Optimise loading criteria - no overdesign
- Specify high, but responsible, levels of recycled material content (structural steelwork, reinforcement, recycled aggregates, cement replacement) and low impact materials
- Consider future demolition and recycling opportunities

2.5.1.4 Superstructure Framing Selection / Option Appraisal

At this stage of the design, it can be valuable to have explored a range of different structural framing solutions, even if the focus may have been whittled down to one potential solution. Maintaining some flexibility to use different construction materials in the later design stages will allow full embodied carbon framing assessments to be undertaken and used to finalise the design.

As Figure 2-15 illustrates, the proposed build includes numerous different uses for the floor plates. This results in different loading and framing requirements. In order to arrive at an optimum solution, a hybrid structure with a variety of structural framing and floor plate types has been proposed. Generally, to achieve the architectural intent (which requires maximum clear spans whilst minimising the structural build-up) an RC frame with PT slabs in the upper floors has been progressed.

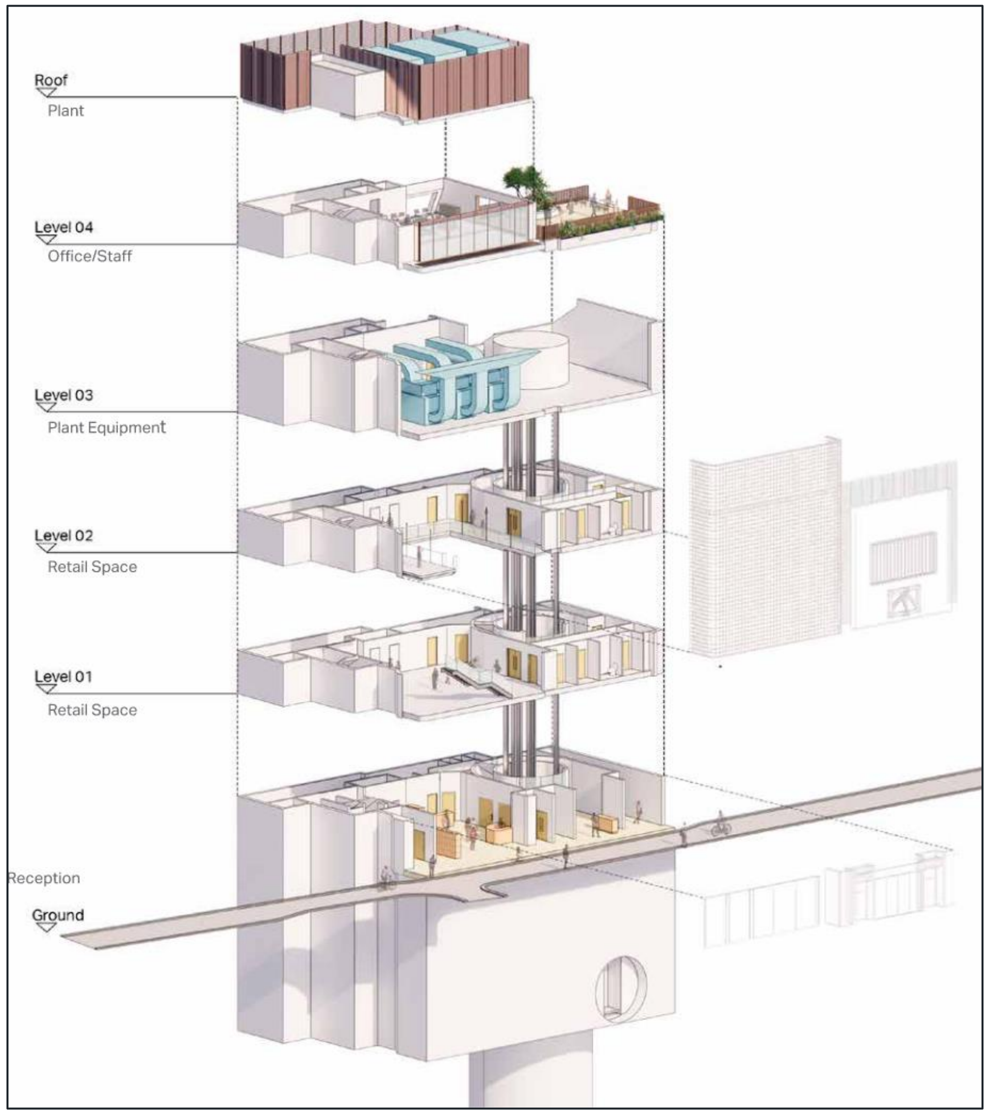

Figure 2-15 – Axonometric Showing the Proposed Combined 38-39 & 40-41 Furnival Street Building and Floor uses

Appendix A summarises and compares the various structural framing and floor options that were considered.

2.5.1.5 Substructure Options

The following methods for retaining structures have been considered:

- Contiguous Pile Wall
- Secant Pile Wall
- Underpinning of existing basement wall

Based on the ground conditions, groundwater level and depth of basement, a contiguous pile wall is proposed as the most efficient retaining structure solution. This offers significant savings when compared to a secant pile wall. Both in terms of construction programme and material use.

2.5.1.6 Designing for Adaptability

Designing for adaptability is an important element of both a circular economy and reduction of whole life carbon. Designing buildings for adaptation aims to ensure that they will be designed to meet future needs such as using the building for use types/ designing for a number of different tenants without compromising the building, consequently increasing the buildings lifespan & reducing carbon from the need to demolish and rebuild the development should adaptation be required in the future.

The Development will ensure that the design is flexible and adaptable therefore increasing the building's lifecycle and providing a building lifespan of at least 50 years. The new structure will include long spanning PT slabs. This will offer flexible column free space with a high load allowance, resulting in an adaptable design.

Most of the project involves refurbishment of the existing Tunnels network. The refurbished and enabled Tunnels network will offer an adaptable and flexible open space to future occupants. In addition, the works at 31-33 High Holborn are refurbishment and minor alterations to the existing structural frame. This increases adaptability of the shaft and Tunnels below by increasing available space and easing access.

The steel frames supporting the first-floor gallery, spiral stair and facade can be adapted and strengthened if necessary in future. This adaptability is a benefit of steel framed buildings but also enables the disassembly of the building at the end of the building's life. The disassembled/unbolted steel sections can be re-used or recycled; the structural frame will be designed for a 50-year service life.

2.5.1.7 Prefabrication, Transportation & waste

Where possible, precast RC elements will be discussed with the contractor at the next stage. These can be prefabricated off site and are likely to include walls, infill panels and the Tunnels lining structure, reducing carbon (A5 emissions) as there will be less packaging associated with the materials. Local sourcing of materials will be investigated which would reduce carbon emissions from transportation of the products (A4 emissions). Precast elements will be designed to be easily transported and assembled on site.

The existing basement walls of 40-41 Furnival Street will be retained during the construction stage to provide temporary support around the top of the excavation. This will mean demolition waste is minimised, again reducing carbon from demolition (impacts of demolition reported separately).

2.5.1.8 Framing – Superstructure

Generally, in order to achieve the architectural intent to maximise clear spans whilst minimising the structural build-up, an RC frame with PT slabs in the upper floors has been progressed.

The weight of the frame in the Level 02 gallery has been reduced by the use of a steel frame therefore, requiring less strengthening/materials for the structure & consequently reducing carbon.

2.5.2 FACADE DESIGN

The existing façade at 38-39 Furnival Street is of dark bricks. Even though the fabric is in poor condition, due to its historical significance, reinstating this design close to its original form. At 40-41 Furnival Street various perforated brick and other constructions were considered before adopting a strategy of using glass blocks to form a translucent curtain wall with large ventilation plenums down from the roof to the plant space at L03 behind the skin of glass bricks.

Three façade types have been considered for 38-39 and 40-41 Furnival Street:

- Perforated Bricks
- Brick Slat Combination
- Glass Brick Façade (Selected option)

Figure 2-16 – Façade options for 38-39 and 40-41 Furnival Street

At 40-41 Furnival Street, the office building faced a challenge with limited ventilation options on its west facade. After exploring various construction methods, the choice was a glass block facade. This design serves multiple purposes: it allows natural light into the front spaces while maintaining privacy for neighbouring areas. The glass blocks create a warm ambiance in the evenings when combined with architectural lighting. To manage nighttime light spillage, strategies include controlling light levels in plant spaces and utilizing automatic internal blinds when needed in public areas. Additionally, the glass block facade on Level 03 not only provides ventilation but also supports sound control with acoustic louvres. The design's practicality extends to including demountable portions for easy access during plant replacement operations (if required). Additionally, the City of London favors glass blocks for their sleek, contemporary look and practical benefits. They allow natural light in, create open spaces, and are durable against diverse weather conditions. Additionally, they're eco-friendly, made from recyclable materials and support the city's commitment to sustainable construction. Their ease of disassembly and recyclability adds to their appeal in creating a green urban landscape.

The design for the 38-39 Furnival Facade follows circular economy commitments, intending to reuse and reinstate as much of the existing fabric as feasible (subject to testing for structural integrity). This primarily involves recycling bricks and precast elements, such as the vent. The plan includes the reinstatement of a hinged lifting beam as a heritage feature that was once part of the facade. The MEP (mechanical, electrical, plumbing) strategy involves reactivating the precast vent as an exhaust for new plant equipment on Level 03. Additionally, the aim is to reinstall and repurpose existing sundry items like precast sills and soffits wherever possible.

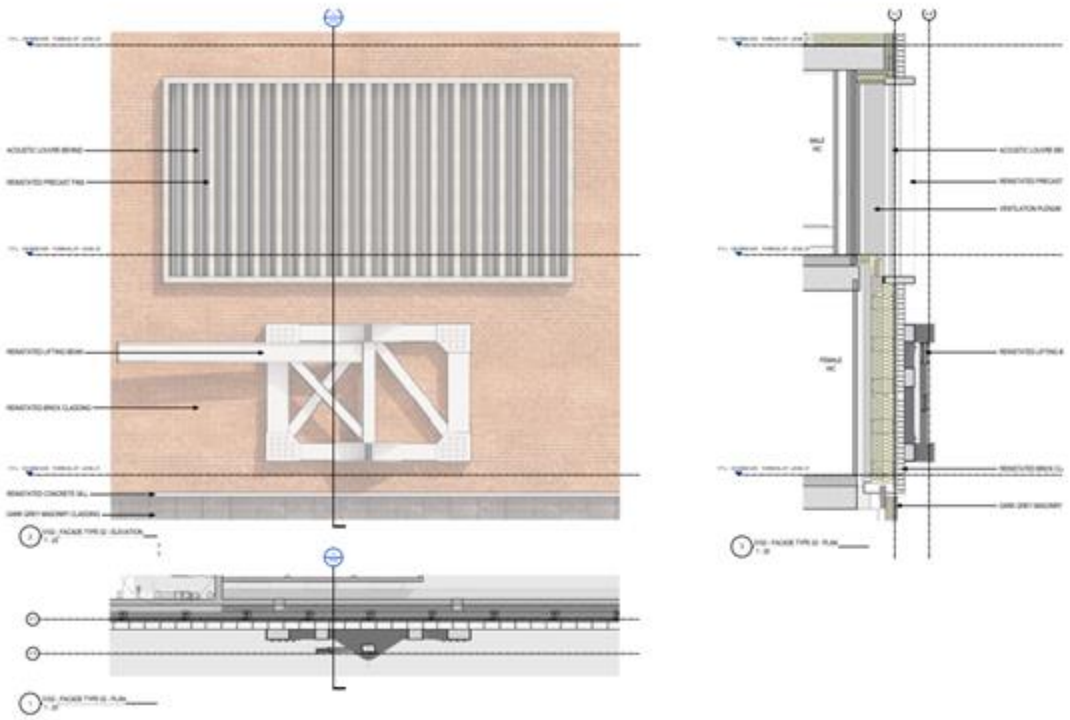

Figure 2-17 – Reinstating the façade at 38-39 Furnival Street

The existing ground floor cladding of 38-39 Furnival Street is a square format cementitious tile in very poor condition. To retain character, it is proposed to match the modulation of the tile in a dark grey masonry material, The intention is to retain and reuse as much as possible of the existing fabric including the sills and soffits to the brick. The Ground floor facade will include full height glazed panels and full height, low profile, glazed, pivot doors for plant and exhibit replacement.

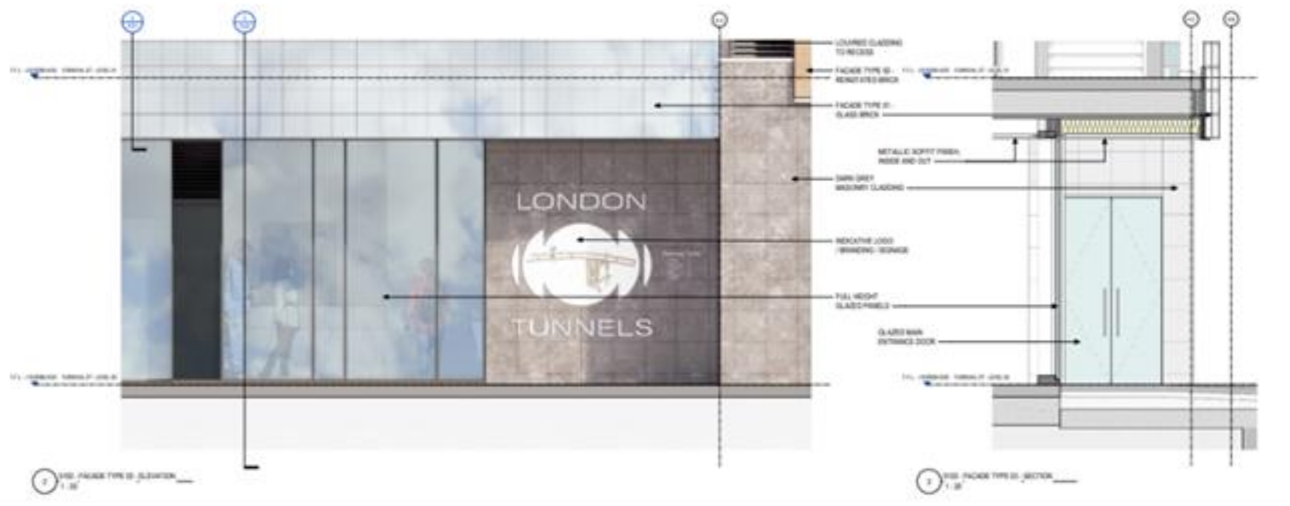

Figure 2-18 – Ground floor façade at 38-39 Furnival Street

The proposed façade for the 31-33 High Holborn suggests that there will be minor upgrade to the façade (Figure 6-6) and the current façade is to be retained.

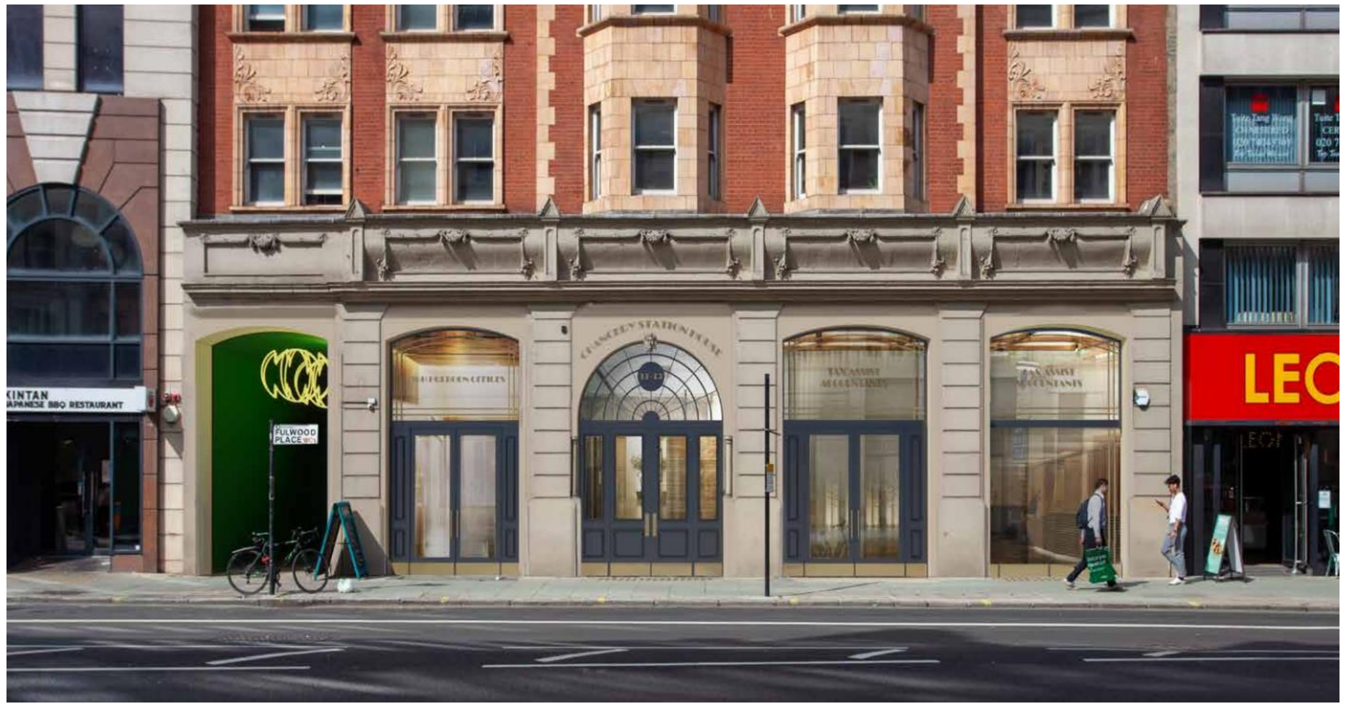

Figure 2-19 –Proposed upgrade to the façade at 31-33 High Holborn

2.5.3 BUILDING SERVICES DESIGN

As this is a refurbishment project, the embodied carbon of Mechanical, Electrical, and Public Health (MEP) services is likely to be one of the largest contributors to the carbon footprint of The London Tunnels. MEP plant and equipment are typically made from materials with a high embodied carbon such as metals and electronic components. Additionally, MEP products have complex supply-chains restricting the amount of data available on these systems making the calculation of the carbon footprint of these products more difficult. Given the substantial material and process requirements, the embodied carbon of the MEP services frequently emerge as significant contributors to the carbon footprint of a retrofit project. Hence, adopting a methodology to measure and reduce the embodied carbon of the MEP design is important to ensure that the design aligns with industry best practice and wider project sustainability objectives.

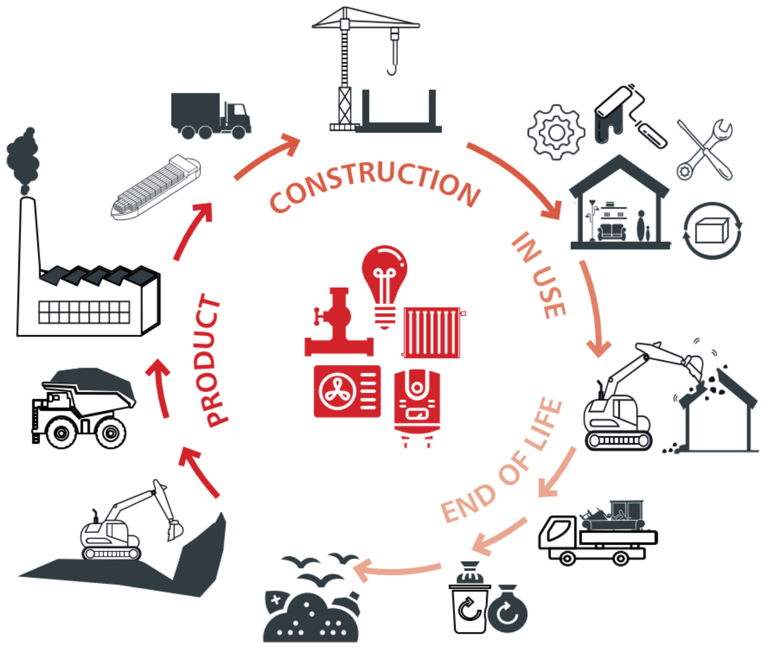

Figure 2-20 – Lifecycle Stages from TM65 (Source: Adapted from the CIBSE TM65 Guidance)

TM65 Calculation Methodology

In response to growing concern about the amount of embodied carbon in building services products, The Chartered Institution of Building Services Engineers (CIBSE) introduced the TM65 (2021) document to guide professionals in quantifying and understanding the embodied carbon associated with building services equipment. This technical memorandum underscores the imperative for a more sustainable approach, recognizing that a significant proportion of a building's whole-life carbon can arise from its services components. The document outlines a methodical approach, detailing steps for the assessment of embodied carbon right from material extraction, manufacturing, and transport to the end-of-life processes, such as waste processing and disposal. Furthermore, TM65 accounts for complexities in product manufacturing and provides recommendations for carbon estimations in the absence of specific data, ensuring a comprehensive, yet adaptable approach for various building services scenarios.

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

One important thing to note is that TM65 only gives a method for undertaking an embodied carbon assessment at a product level. A number of further assumptions need to be made in order to apply this methodology to a whole building services design. Therefore, it is appropriate (given the stage of design) to also add a ‘quantities uncertainty factor’ to account for elements of the design that haven’t been accounted for during concept design. This can then be reduced as the design progresses and design certainty increases.

Key Design Concepts

Whilst specific recommendations can and should be made to reduce the embodied carbon of a specific building design. There are some general principles that can be applied across all building services designs in order to reduce their embodied carbon contribution. These have each been considered when developing the design outlined in the MEP report.

- **Measure:** Undertake detailed TM65 assessment of MEP to feed into WLC assessment and ensure that product specifications include embodied carbon information (EPDs or CIBSE TM65 forms) in their product information.
- **Reduce:** Avoid over provision of plant, through detailed load assessment, building optimisation and correct sizing of MEP equipment. Reduce services distribution runs by correctly locating central plant and risers. Reduce weight of supporting structures and required reinforcement. Remove systems where possible.
- **Materials:** Consider low carbon or natural materials. For example, using timber instead of metal, or using natural wool insulation over polyethylene foam.
- **Refrigerant:** Use low GWP refrigerants and ensure refrigerant leakage is carefully considered in WLC analysis

Measures Taken to Reduce Whole Life Carbon

The building services provision to the Tunnels must be substantially upgraded as part of this development, in order to enable the increased occupant loads. The proposed design will feed the services from the proposed building on Furnival Street. For the mechanical systems, this design includes three 600kW cooling towers, two 600 kW water-cooled chillers and one 400kW heat-recovery chiller. The heat-recovery chiller will utilise waste heat extracted from Tunnels to provide heating and hot water for the site. There will also be a provision for buffer vessels on the CHW and LTHW systems that will be used to reduce system cycles, improving the system stability and energy performance.

This central plant design was optimised to minimise the operational energy and embodied carbon within the project constraints. A Stage 2 assessment of the embodied carbon of the full MEP system has been undertaken following guidance outlined by CIBSE TM65. This has captured more detail on the embodied carbon of MEP systems than is usually undertaken at a concept stage level of design. However, undertaking this process at such an early stage has been invaluable in order to highlight areas of the design that have high embodied carbon and enact design changes early on in the design to lower the overall embodied carbon contribution of the MEP system.

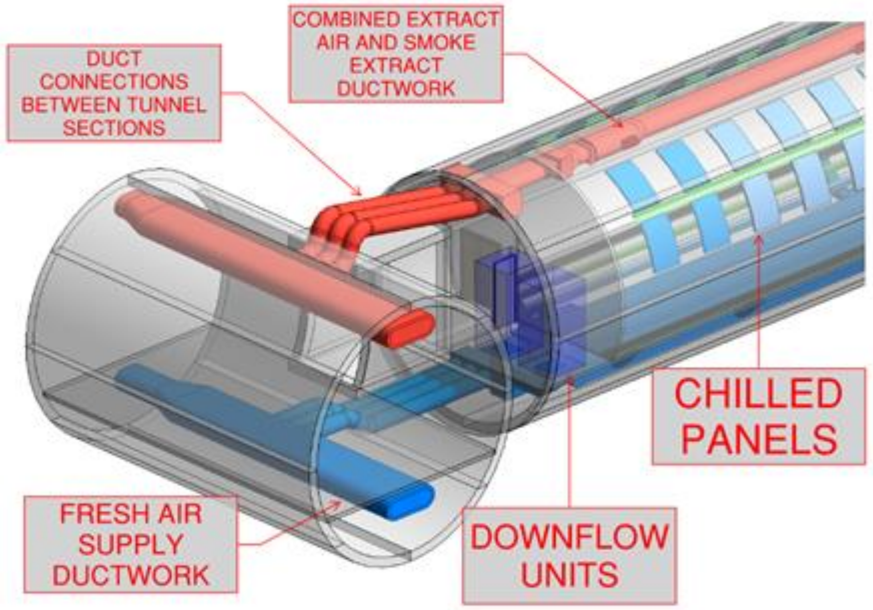

Figure 2-21 – 3D View of Tunnels Ventilation Strategy

A detailed load assessment has been undertaken to ensure that both mechanical and electrical equipment has been sized correctly and not over provisioned. Alternative central plant designs were considered and ultimately rejected. For example, ground source heat pumps were initially considered as a potential option, however this was not deemed feasible as there was found to be limited physical space for boreholes or pipe loops, and the ground has limited heat absorption capacity, especially for high loads. Similarly, air source heat pumps were ultimately rejected as there is limited roof area for the plant, and there were concerns around the acoustic impact this design would have on surrounding buildings. Connection to a district heating or cooling network was also considered, however the networks are not currently extended to the area. A provision will be made for future connection to Citigen network, as this may become possible in the future.

The Avenues and Streets within the Tunnels are supplied with minimum fresh air via combined general ventilation and smoke control ductwork. The duct sizes will be minimised to the smoke requirement to save material and embodied carbon. Chilled panels will be included within the Avenues and Streets. These locally positioned passive panels can be used to absorb heat, offering the ability to capture heat from equipment such as projectors and screens. Their inclusion in the design also offers the ability to cool the space during unoccupied hours using only cooling towers. This will avoid the energy usage associated with operating the chillers and reduce the operational energy of the development.

There is an opportunity here to explore the impact of using lower carbon materials for ductwork, such as plastic ductwork sections. This, along with other opportunities to utilise lower carbon materials, will be explored at the next stage along with the updated Stage 3 TM65 assessment.

Refrigerant volume has been reduced across the project by using packaged chiller and heat pump units where no refrigerant works will need to be undertaken on site. Furthermore, no VRF/VRV refrigerant systems have been included in the design. A low GWP refrigerant R1234ze has been selected, as shown by Table 2-3 to further reduce the environmental impact of the refrigerant system.

Table 2-3– Proposed Refrigerants for The London Tunnels (Informing MEP Services of WLCA, as Advised by MEP Engineer)

Refrigerant Name	Initial Charge(kg)	Annual Leakage Rate %	Refrigerant GWP Over 100 Years ($kgCO_2eeq$)	End of Life Recovery Rate %
R1234ze (E)	500	2	1	99

2.5.4 OPERATIONAL ENERGY (B6)

The module B6 has been taken from the findings of the CIBSE TM54 analysis. The key strategies for the Proposed Development outlined within the Operational Energy study are considered to maximise the potential carbon savings which can be achieved on the application site through:

- Low energy lighting;
- Optimisation of the AV design in terms of the difference in energy between LED screens and projectors;
- Low heating loads due to the thermal mass provided by the ground around the tunnel; and
- High efficiency cooling provided by water cooled chillers.

2.5.5 SUMMARY OF CIRCULAR ECONOMY DESIGN PRINCIPLES

A combination of Circular Economy Design Principles for existing buildings and new buildings were followed and incorporated into the Proposed Development (Figure 2-22 & Figure 2-23) due to the retention of the existing buildings and the demolition & redevelopment of 38-39 and 40-41 Furnival Street. Specific measures on circular economy can be observed within the Circular Economy Statement and, where appropriate the Design Optimisation incorporating carbon reduction can be observed throughout this report.

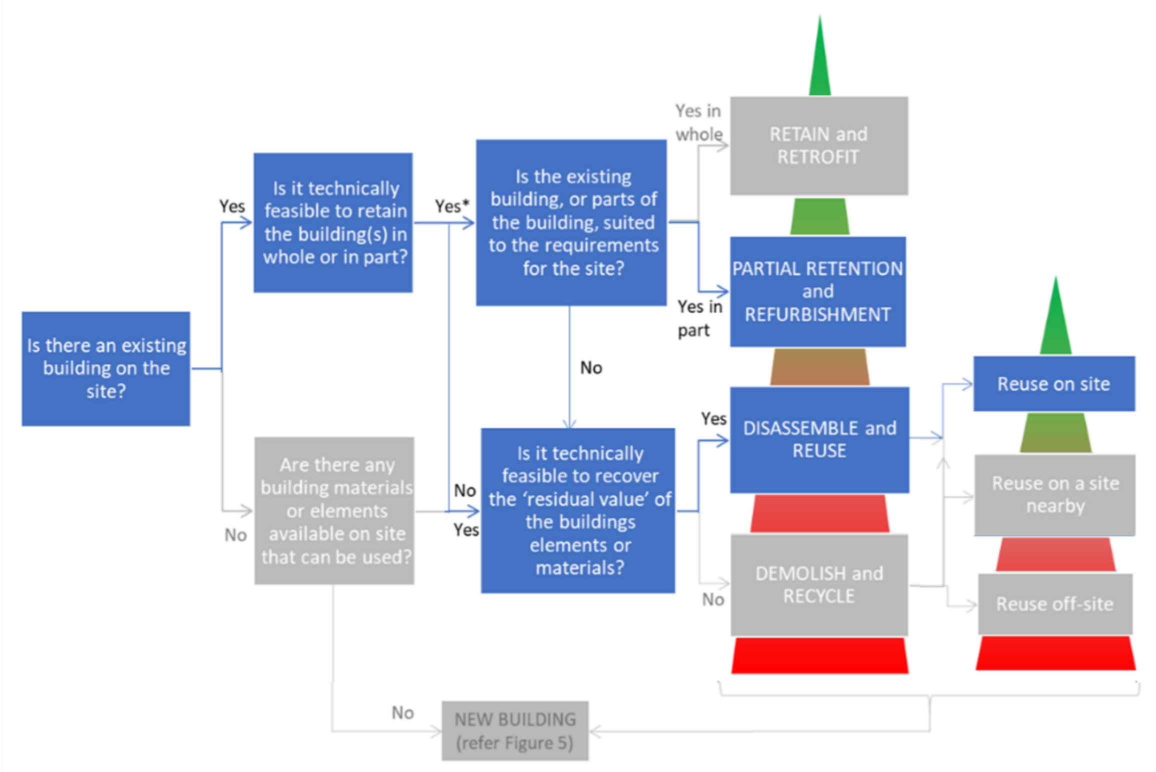

Figure 2-22 – Circular Economy Design Principles for Existing Buildings (Source: Adapted from the London Plan CES Guidance, March 2022)

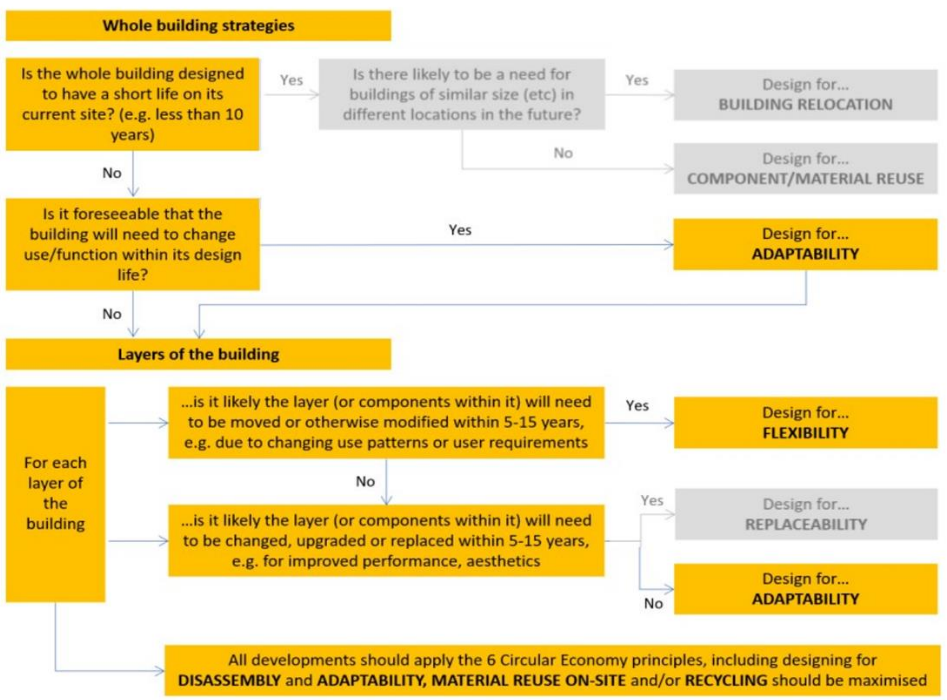

Figure 2-23 – Circular Economy Design Principles for New Buildings (Source: Adapted from the London Plan CES Guidance, March 2022)

3 WHOLE LIFE CARBON ASSESSMENT

3.1 APPROACH

As greater carbon reduction can be achieved if a Whole Life Carbon (WLC) Assessment is carried out at the early design stages (Figure 3-1), WSP has been commissioned to carry out a WLC Assessment at RIBA Stage 2 of the design process.

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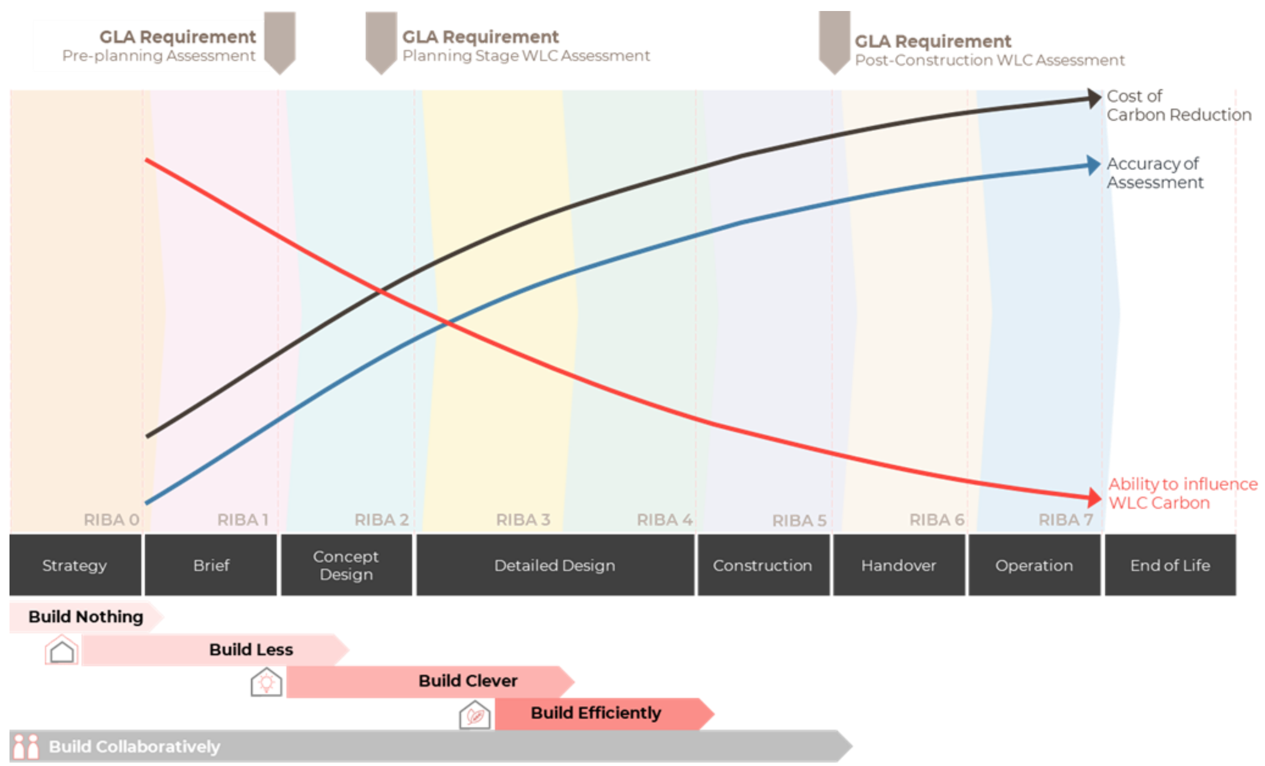

Figure 3-1 – Carbon Reduction at Key Design Stages

This section of the report summarises the methodology used for the WLC Assessment conducted for the Proposed Development which provides a quantitative account of a building's emissions.

3.2 METHODOLOGY

In line with the UK standard practice EN15978:2011 and the RICS Professional Statement Guidance for WLC Assessments for the Built Environment (2017), this assessment covers all modules from A1–C4, while module D is reported separately as seen in Figure 3-2. Since writing this RICS 2023 has been made available. RICS 2017 has been used due to the assessment software (OneClick LCA) not yet accounting for this new assessment guidance.

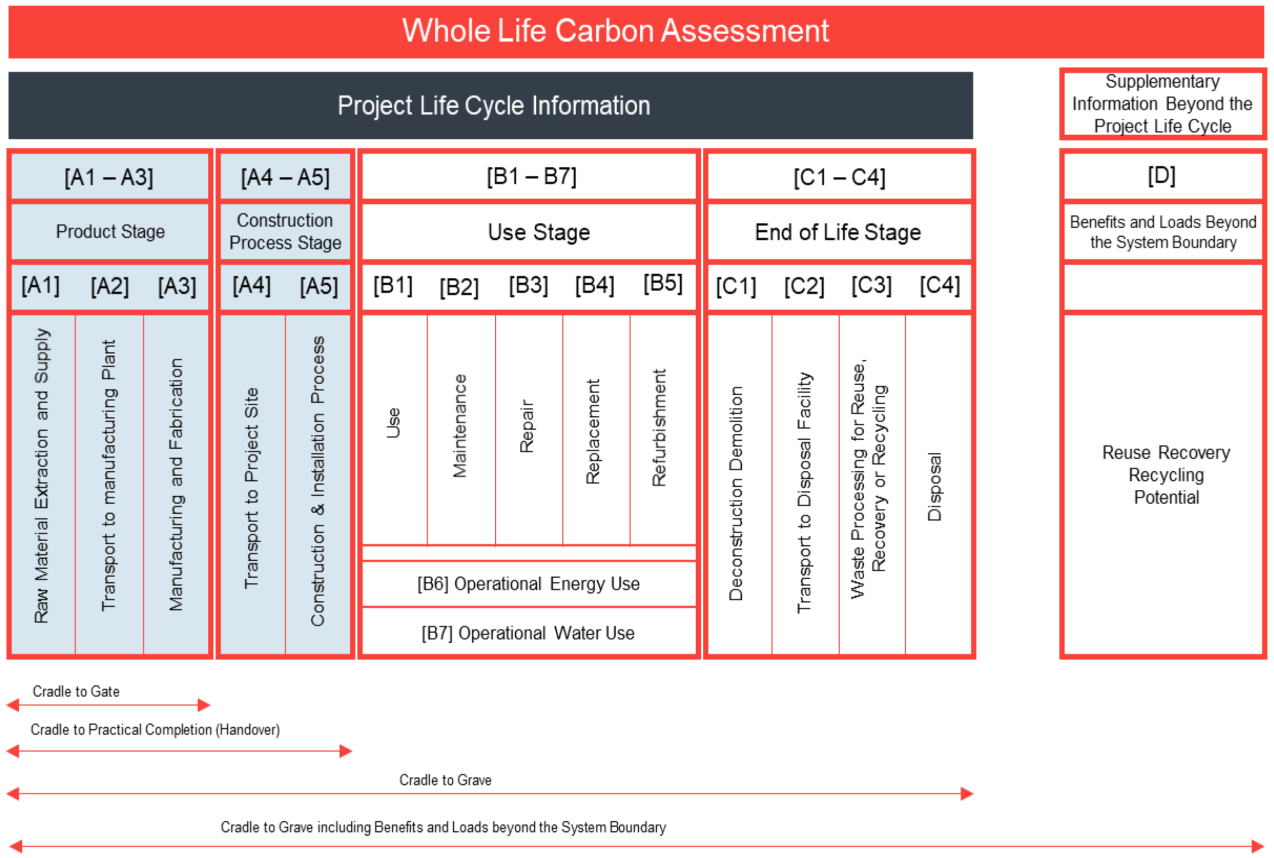

Figure 3-2 – LCA Modules in Line with EN 15978 & RICS Guidance 2017

The four main stages are defined as follows:

- **Product** (A1-A3 – also known as cradle to gate)
  These modules include the $kgCO_2e$ released during extraction, processing, manufacture (including prefabrication of components or elements) and transportation of materials between these processes, until the product leaves the factory gates to be taken to site. Note that recycled content of a product affects the $kgCO_2e$ released in modules A1-A3. Whether it is recycled after its end of life or not, does not affect the A1-A3 impact of the project being considered, this is considered in module D which is reported separately.
- **Construction Process** (A4-A5)
  These modules include the $kgCO_2e$ released during transportation of materials/products to site, energy usage due to activities on site (site huts, machinery use etc) and the $kgCO_2e$ associated with the production, transportation, and end of life processing of materials used on site.
- **Use** (B1-B7)
  These modules include the $kgCO_2e$ released due to use, maintenance, repair, replacement, refurbishment and operational energy and water while the building is in use. Module B4 (replacement) is often the focus of the use stage when embodied carbon is being considered.
- **End of Life** (C1-C4)
  These modules include the $kgCO_2e$ released during decommissioning, stripping out, demolition, deconstruction, transportation of materials away from the site, waste processing and the disposal of materials.
- There is one additional stage beyond the life cycle of the asset that is intended to provide a broader view of its environmental impacts: Benefits and loads beyond the system boundary (Module D).

This estimates any net $kgCO_2e$ benefits of loads beyond the project's life cycle associated with but not limited to:

- Recycling of materials e.g., use of scrap steel (rather than virgin iron) in steelmaking on future projects;
- Energy recovered from materials e.g., energy generated by incinerating timber products; and
- Full reuse of materials/products when compared to the standard practice/standard product it would be replacing.

The software that was used to conduct the assessment was OneClick LCA. It has been approved by the BRE and it is compliant to BS EN 1598:2011, ISO 21929, ISO 14040 and EN 15804. The metric for assessing the carbon emissions is Global Warming Potential (GWP) which is expressed in units of CO_2 equivalent (CO_2e). Table 3-1 gives a breakdown of the building elements that have been included in the assessment. The analysis includes all of the building elements accounted for in the information provided by the Design Team.

Table 3-1 – Building Elements Included Based on Stage 2 Information

	Building Element (NRM Level 2)	Basis for Information
Demolition	0.1 Toxic/hazardous/contaminated material treatment	N/A
	0.2 Major demolition works	
0 Facilitating works	0.3 & 0.5 Temporary or enabling works	Excavation quantities were provided in the Cost Plan.
	0.4 Specialist groundworks	
1 Substructure	1.1 Substructure	Material quantities were provided in the Cost Plan.
2. Superstructure	2.1 Frame	Material quantities were provided in the Cost Plan with supplemental information from the Design Team.
	2.2 Upper floors incl. balconies	
	2.3 Roof	
	2.4 Stairs and ramps	
	2.5 External walls	Material quantities were provided in the Cost Plan with supplemental information from the Design Team.
	2.6 Windows and external doors	
	2.7 Internal walls and partitions	
	2.8 Internal doors	
3 Finishes	3.1 Wall finishes	

	Building Element (NRM Level 2)	Basis for Information
	3.2 Floor finishes	Material quantities were provided in the Cost Plan with supplemental information from the Design Team.
	3.3 Ceiling finishes	
4 Fittings, furnishings, and equipment (FF&E)	4.1 Fittings, furnishings & equipment incl. building-related* and non-building-related**	Allowance accounted for based on cost of element in relation to the total WLC figure (approx. 1%).
5 Building services/MEP	5.1–5.14 Services incl. building-related* and nonbuilding-related**	A TM65 assessment was used to assess the carbon implications from MEP Services. Lifecycle stages were broken down by MEP Engineer. As the design progresses opportunities to reduce carbon will be further explored. Note: the TM65 assessment includes a 30% buffer factor to account for uncertainty at early design stages.
6 Prefabricated buildings and building units	6.1 Prefabricated buildings and building units	N/A
7 Work to existing building	7.1 Minor demolition and alteration works	N/A
8 External works	8.1 Site preparation works	Excluded from the assessment due to lack of available data.
	8.2 Roads, paths, paving and surfacing	Based on Cost Plan with supplemental information from Design Team.
	8.3 Soft landscaping, planting and irrigation systems	There were no works accounted for in the information provided.
	8.4 Fencing, railings, and walls	
	8.5 External fixtures	
	8.6 External drainage	
	8.7 External services	
	8.8 Minor building works and ancillary buildings	

A minimum of 95% of the material quantities allocated to each building element category is accounted for at each stage of the assessment. The information used for this assessment is quality assured by using the cost plan in addition to material quantities provided by the Design Team based on Stage 2 information.

> '*All quantities relating to 'existing structure' are based on high level assumptions and not on current as-built information. As a result, numbers are approximate and subject to a significant margin of error.*'

3.3 TARGETS & BENCHMARKS

A range of targets and benchmarks have been published across the industry by a number of different bodies. These have been summarised below. It is important to note that this assessment has been conducted based on Stage 2 design information while the RIBA targets mentioned below are 'built' rather than 'design' targets. Furthermore, the benchmark listed are for retail as there is a lack of data and benchmarks for cultural spaces and buildings with high heritage value. On this basis and due to the bespoke nature of the Site, the industry available benchmarks are not applicable to the Proposed Development. They have however been left in as a reference and to provide context on the impacts associated with modules B1-5 and C1-4 as the LETI targets relate only to upfront embodied carbon (A1-A5).

Environmental and sustainability targets include BREEAM 'Very Good' and aspiring to achieve; Excellent' – BREEAM Refurbishment; and RFO 2014 Guidance.

3.3.1 GREATER LONDON AUTHORITY (GLA)

In March 2022 the GLA released an update of their WLC Assessment guidance. The document includes information on design principles and WLC benchmarks to aid planning applicants in designing buildings that have low operational and embodied carbon. Although the development is not referrable to the GLA, the GLA benchmarks have been used as per Local Authority guidance.

Table 3-2 – GLA Retail Benchmarks

	Module A1-A5 (Excluding Sequestered Carbon)	Modules B-C (Excluding B6 & B7)	Modules A-C (Excluding B6 & B7; Including Sequestered Carbon)
WLC Benchmark	<850	<200	<1050
Aspirational WLC Benchmark	<550	<140	<690

3.3.2 LONDON ENERGY TRANSFORMATION INITIATIVE (LETI)

LETI was established to support the transition of the capital's-built environment to net zero carbon. Despite being originally aimed at London they have been widely adopted across the sector in the UK and provide a useful reference point for the upfront embodied carbon of building designs.

3.3.3 ROYAL INSTITUTE OF BRITISH ARCHITECTS (RIBA)

RIBA released an initial (2019) version of their 2030 Challenge which set out total embodied carbon (A1-A5, B1-B5, C1-C4) performance targets, rather than the upfront (A1-A5) targets that were published by LETI. These original figures were not comparable as the scopes used by RIBA and LETI were not consistent. In 2021 RIBA revised their 2030 challenge and their scopes now align to enable comparison using a coloured banding system shown below.

3.3.4 THE ALIGNED TARGERS (LETI & RIBA)

For upfront embodied carbon, Figure 3-3, the LETI 2020 target for retail developments is Band C at 550 $kgCO_2e/m^2$. The LETI 2030 target is Band A at 300 $kgCO_2e/m^2$. For whole life embodied carbon, Figure 3-4, The RIBA 2030 Built Target for retail developments is Band B at 535 $kgCO_2e/m^2$. Bands remain constant throughout.

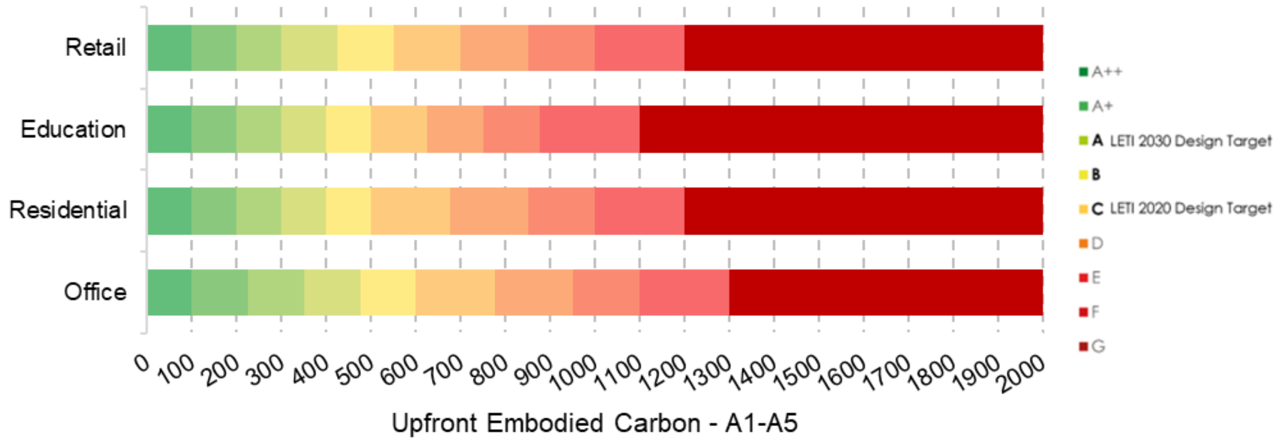

Figure 3-3 – Upfront Embodied Carbon Targets (Design)

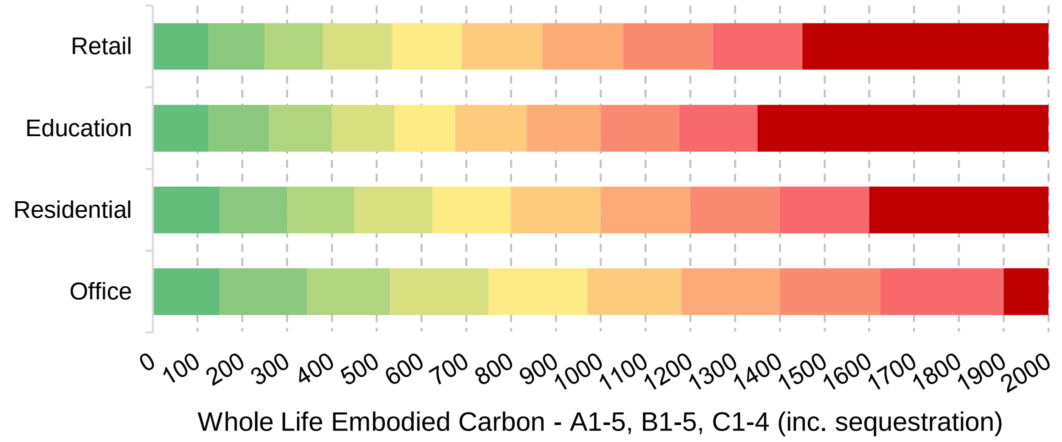

Figure 3-4 – Whole Life Embodied Carbon Targets (Built)

4 ASSUMPTIONS

Assumptions were made at each lifecycle stage, which can be observed in Table 4-1.

Table 4-1 – Assumptions Made at Lifecycle Stages

Lifecycle Stage	Assumptions
Product Stage (A1 – A3)	Calculated using EPDs which align with the exact product and/or material specification or the most applicable similar product.
Construction Process Stage (A4 – A5)	Transportation to site (A4) - calculated using RICS assumptions: 50 km (locally sourced materials like concrete -mix) 300 km (national sourced materials) 1500 km (internationally sourced within the EU) Site operations including construction waste (A5) - based on the project value per £1 million (as per the RICS guidance).
Use Stage (B1 – B5)	Use (B1) includes the impact of refrigerant leakage at leakage rate observed in Table 2-3. Maintenance (B2) and Repair (B3) have been accounted for in the results, expressed as a % of material repaired per year. B2 has been assumed to be 1% of A1-A5 whilst B3 is 25% of B2 in line with GLA guidance. Replacement (B4) and Refurbishment (B5) is based on the product specific service life and where applicable, RICS default service life. FFE was assumed to be approx. 1% of the WLC.
Operational Energy Use (B6)	Based on the Energy Strategy (November 2023)
Operational Water Use (B7)	Based on information provided by Public Health Engineer.
End of Life Stage (C1-C4)	Based on End of Life (EoL) Market Scenarios (see Section 4.3) C1 estimated as % of WLC figure for each building element.
Benefits and Load Beyond System Boundaries (D)	

4.1 BUILDING LIFE

This WLC Assessment was conducted assuming a 60-year lifecycle. It is accepted that many structures will have a longer useful life, however a cut-off value has been assumed in accordance with the RICS Guidance 2017 to ensure that End of Life (EoL) scenarios and their associated emissions are accounted for in the assessment.

4.2 FACADE ASSUMPTIONS

The design focuses on sustainable development goals, aiming to reduce operational carbon, minimize embodied carbon, and prioritize durability and disassembly.

Please note that the current assessment is carried out with OneClick LCA, whereas any Façade Engineering carbon analysis likely utilised a discipline-specific methodology in line with the CWCT (Centre for Window and Cladding Technology) guidance.

The Design Team acknowledges that these two approaches may result in discrepancies between the corresponding carbon emissions results. OneClick LCA is currently the only accredited consistent cross-discipline methodology to evaluate carbon emissions, however considering the different nature of the assessed elements, complex building components, such as façades, may not necessarily reflect product-based data or the comprehensive set of sub-components that characterises them, relying on more generic assumptions.

It is often spoken about the "iceberg analogy" when referring to façade design. This highlights the hidden components that are to be addressed in a façade system when embodied carbon is calculated. Most of the sub-components are heavy embodied carbon contributors however at the early stage of the design are not yet fully defined, hence an allowance for those elements in an early-stage assessment helps providing a realistic and achievable assumption to be further explored at later stages.

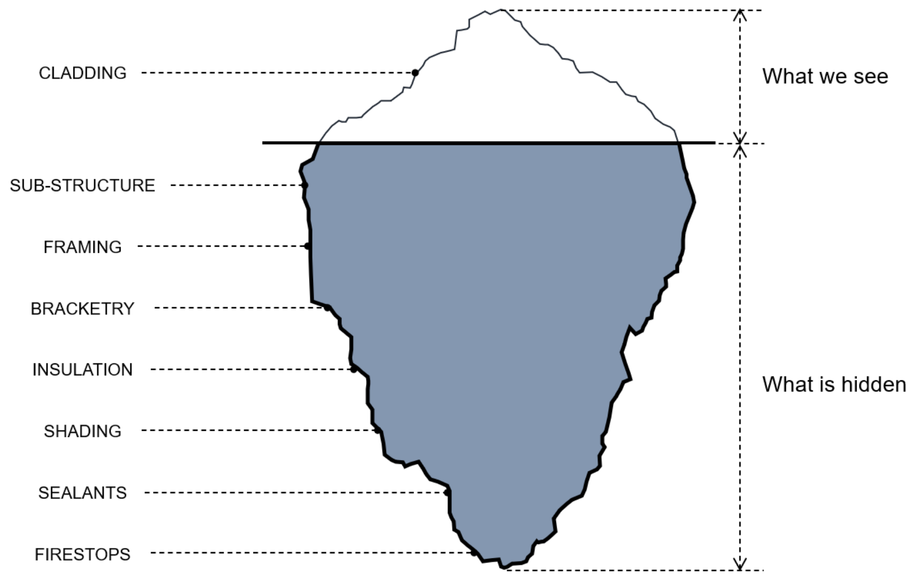

Figure 4-1 – The "Iceberg Analogy" for Façade Hidden Components

4.3 END OF LIFE SCENARIOS (MODULE D)

The Proposed Development has been designed and constructed to reduce material demands as far as practicable and will use systems, elements and materials that can be reused and/or recycled at the end of their useful life.

The building structure has been designed with the industry design life of 50 years (as per the British Standards and Eurocodes).

Modularity will be encouraged, where feasible to allow for disassembly and reuse at the end of the building's useful life. Building information will be stored to allow for end-of-life strategy, future reuse, disassembly, and waste reduction/avoidance.

The Proposed Development will follow the default EoL scenarios (UK Statistics on Waste (2016) from DEFRA) for metals and timber whilst construction and demolition-related items will follow the London Plan Policy Targets.

5 THIRD PARTY VERIFICATION

Civic Engineers will undertake a third-party review of the WLCA. The comments will be appended post submission, when available.

6 RESULTS

Three scenarios have been considered to include for current design development and future potential scenarios that may be included in the CAT B design. These are as follows:

- **Low Scenario**: the baseline-low case scenario represents the base building CAT A design where the building operates with anticipated occupancy and opening hours but there is no energy intensive audio-visual equipment installed.
- **Medium Scenario**: For the Medium Scenario, the AV system is assumed to be mostly projectors with some screens, equivalent to roughly 50% AV coverage of the high scenario. This scenario lines up with the Medium Scenario in the Be Seen energy analysis.
- **High Scenario:** the high scenario is based on anticipated occupancy and opening hours with a higher proportion of the Tunnels containing AV equipment. The AV system in this case is assumed to be mostly LED screens with some projectors. This scenario lines up with the High and Worst Scenario in the Be Seen energy analysis.

The whole life carbon for these three scenarios and has been reported in Table 6-1. The medium scenario has been used as the basis for this assessment.

The benefits associated with the biogenic materials equate to -6 kgCO_2e/m^2 resulting from the internal doors, and finishes. Carbon savings have also been achieved by specifying low carbon materials where feasible in addition to design optimisation observed throughout this report.

Operational energy was measured in line with the TM54 methodology and using the latest SAP10.2 carbon factor (B6) over a 60-year period. Additionally, Operational Water use was calculated by a Public Health Engineer. The carbon implications resulting from B6 & B7 are 11,583 tCO_2e.

The impact from the temporary works results in 44 kg CO_2e/m^2 for upfront carbon (A1-A5) and 50 kg CO_2e/m^2 for whole life carbon. This figure is reported separately and not included in the results presented throughout this report.

Table 6-1 – The London Tunnels Compared with GLA Retail Benchmarks

TOTAL kg CO_2e/m^2 GIA	Module A1-A5 (Excluding Sequestered Carbon)	Modules B-C (Excluding B6 & B7)	Modules A-C (Excluding B6 & B7; Including Sequestered Carbon)
Low Scenario	581	380	961
Medium Scenario	745	914	1,652
High Scenario	906	1,427	2,333
GLA Benchmark	<850	<200	<1050
GLA Aspirational Benchmark	<550	<140	<690

As observed by Table 6-1 the Proposed Development has been compared with the GLA retail benchmarks as there is no available benchmark associated with the specific use of The London Tunnels. The low scenario would result in an upfront figure of 581 kg CO_2e/m^2 which is above the GLA aspirational benchmark of 550 kg CO_2e/m^2, the whole life carbon for this scenario would also result in the GLA benchmark being met although the aspirational benchmark exceeded. The medium scenario has been proposed throughout this report, the Whole Life Carbon for the medium scenario is higher than the GLA WLC benchmark of <**1,050** kg CO_2e/m^2 for retail buildings. Modules A1-A5 result in **745** kg CO_2e/m^2 which is lower than the GLA upfront benchmark of <850 kg CO_2e/m^2. Modules B & C are estimated to produce 880 kg CO_2e/m^2 which is higher than the GLA benchmark whilst, although not included in the WLC figure, B6 & B7 are estimated to produce 11,583 t CO_2e. The high scenario would result in 906 kg CO_2e/m^2 for upfront carbon and 2,333 kg CO_2e/m^2 for whole life carbon which would exceed the GLA benchmark quite significantly, particularly for whole life carbon. The screens and the projectors are the highest contributors to both upfront and whole life carbon emissions. As can be observed, modules B-C are significant contributors to the carbon, consisting predominantly of lifecycle stage B4 (replacement) accounting for approximately 50% of WLC emissions for the medium scenario, with A1-A3 materials being the second largest contributor to this.

However, the efficient use of materials in addition to designing out waste throughout the design and construction process has led to significant reductions in embodied emissions which can be observed throughout this report. Various scenarios have been investigated as outlined above and the impact of screens has been acknowledged by the design team and will be taken into consideration when developing the CAT B design through product selection, compensating measures in other areas and optimised AV design.

6.1 DETALED RESULTS FOR THE MEDIUM SCENARIO

As per GLA guidance the figures reported below are associated with the whole Proposed Development. The results of the WLC Assessment for the Medium Scenario are shown below, illustrated in three main breakdowns, firstly by lifecycle stage, Figure 6-1, secondly by building element, Figure 6-2 & Figure 6-3 with a more detailed breakdown provided in Figure 6-4. Table 6-2 provides a breakdown by lifecycle stage and building element.

As can be observed by Figure 6-1, the largest contributor to the buildings lifecycle stage emissions are B1-B5, accounting for approximately 52%. The majority of these emissions are associated with the B4 (replacement) lifecycle stage, consisting primarily of MEP services (B4 accounting for 63% of MEP services emissions) which is due to the multiple replacements required for the screens and the projectors throughout the tunnels. The second largest contributor to lifecycle stage emissions is the product stage (A1-A3), accounting for approximately 41% of emissions. This is largely due to the screens, projectors, concrete, rebar and flooring within the Tunnels although the retention of the existing development has likely resulted in carbon savings, limiting the sourcing required for new materials. A4-A5 (transport and construction) and C1-C4 (end of life) account for 4% & 3% of lifecycle stage emissions. The low carbon from the end of life (C1-C4) is likely due to the Proposed Development using the Market Scenarios approach where systems, elements and materials will be reused and/or recycled at the end of their useful life. The Proposed Development will follow the default EoL scenarios (UK Statistics on Waste (2016) from DEFRA) for metals and timber whilst construction and demolition-related items will follow the London Plan Policy Targets.

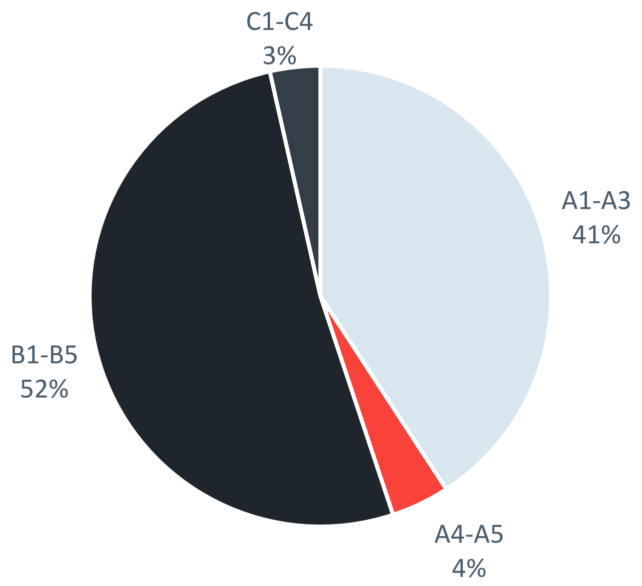

Figure 6-1 – Total kgCO2e/m²- Lifecycle Stages (Excluding B6 & B7)

As observed in Figure 6-2 the MEP services is the largest contributor to upfront emissions, accounting for approximately 50%, followed by the superstructure (20%), substructure (14%) and finishes (10%). Of this 50% 44% is due to the AV system. The specification of up to 25% GGBS in concrete has resulted in a lower contribution for structural elements than if the RICS guidance specification was used. Additionally, the retention of much of the buildings above ground & the Tunnels has resulted in a lower carbon contribution for many elements such as but not limited to the substructure, façade & superstructure.

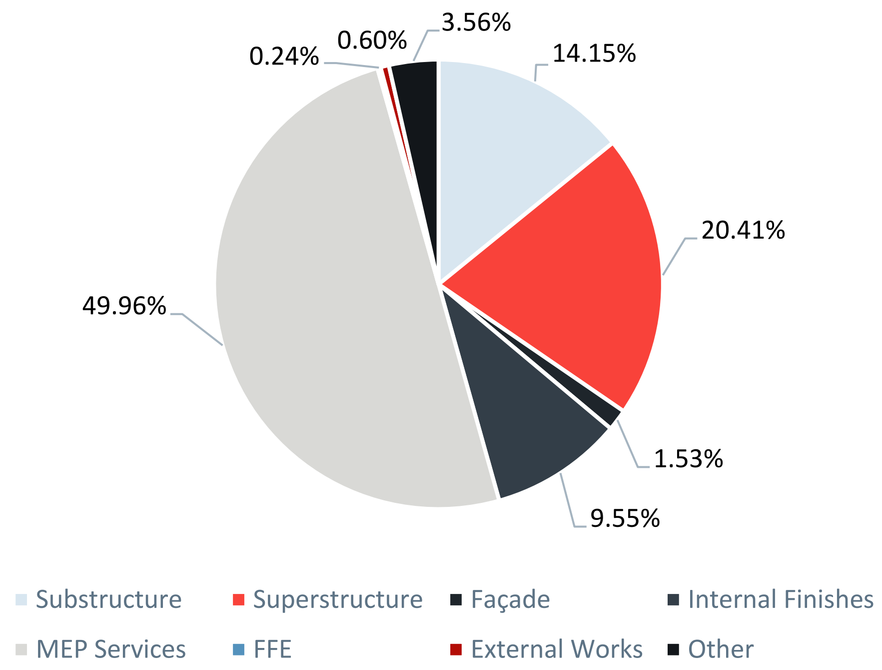

Figure 6-2 – Upfront Carbon (A1-A5) Total kgCO2e/m²-Building Element

As can be observed by Figure 6-3 the MEP services (70%) and the superstructure (10%) are the largest contributor to whole life carbon emissions, followed by the internal finishes (8%), substructure (8%), & construction site emissions ('other') (2%). There are very few emissions associated with façade, FFE & external works.

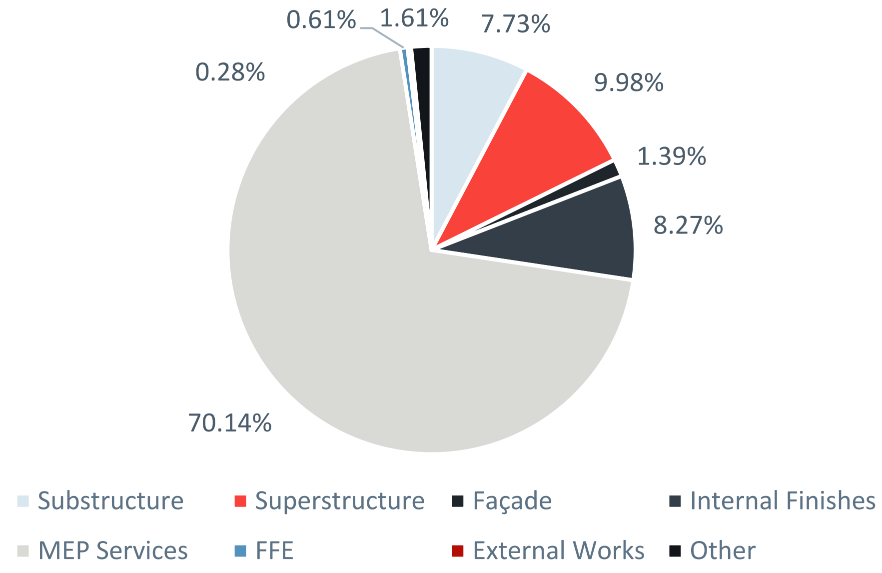

Figure 6-3 – Whole Life Carbon Total kgCO₂e/m²-Building Element (Excluding B6 & B7)

A more detailed breakdown can be observed in Figure 6-4 . MEP services are the largest contributor to whole life lifecycle stage emissions when compared to a more detailed breakdown of the building elements consisting mainly of the screens and the projectors. Of this 70%, 60% is due to the AV systems. The finishes is the second largest contributor to this accounting for approximately 8% of emissions, followed by the substructure (8%) & upper floors (6%).

Due to a % contribution being applied to FFE it should be noted that this element may be over/underestimated. Additionally, the TM65 used to calculate the impact of MEP Services uses a 30% buffer factor to account for uncertainty at early design stages, this it anticipated to reduce as the design progresses. Consequently this figure may be over-estimated.

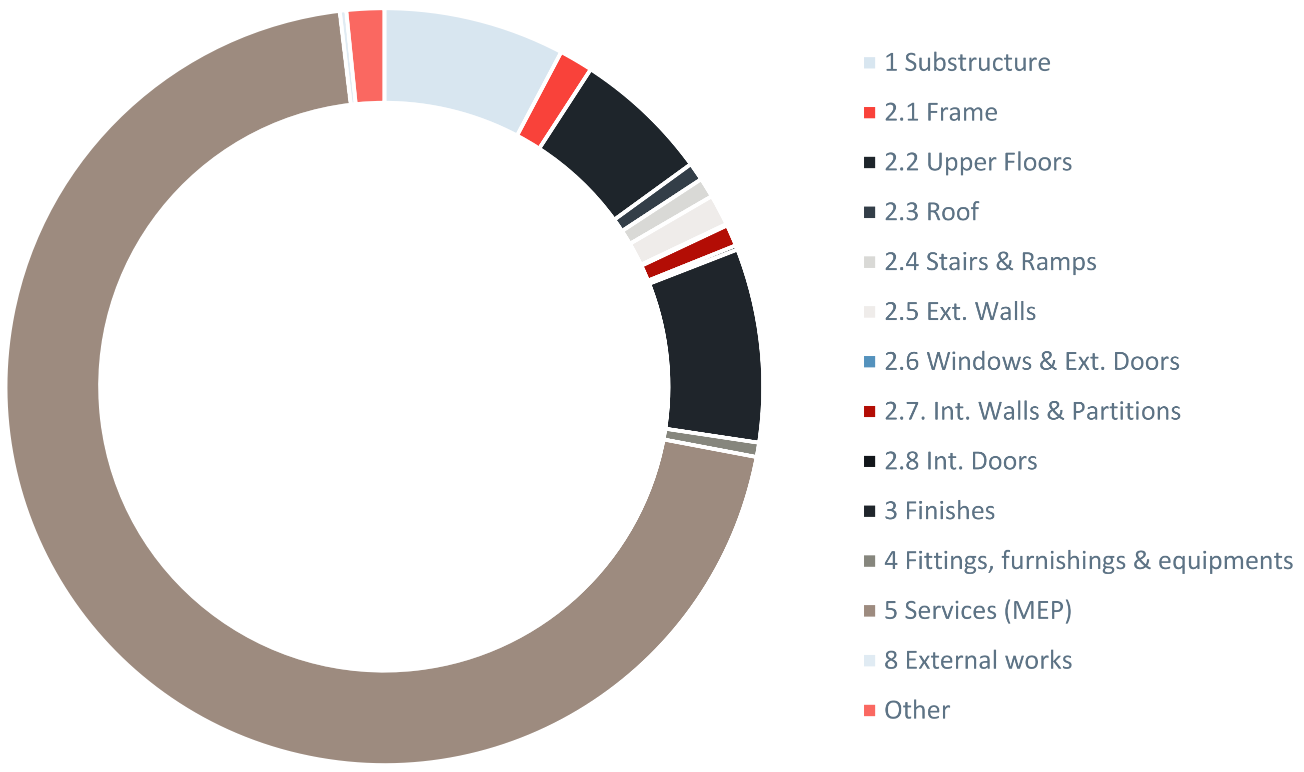

Figure 6-4 – Detailed Breakdown of Building Elements WLC Contribution

The estimated carbon emissions associated with the development were compared against the GLA benchmarks for retail buildings. The London Tunnels has been compared against the GLA retail benchmarks (as this is the most applicable GLA benchmark available), this comparison is not necessarily the most appropriate due to the bespoke nature of the project with proposed uses as a museum & event space. Figure 6-5**Error! Reference source not found.** shows a breakdown of the estimated performance of the development in comparison with GLA benchmarks.

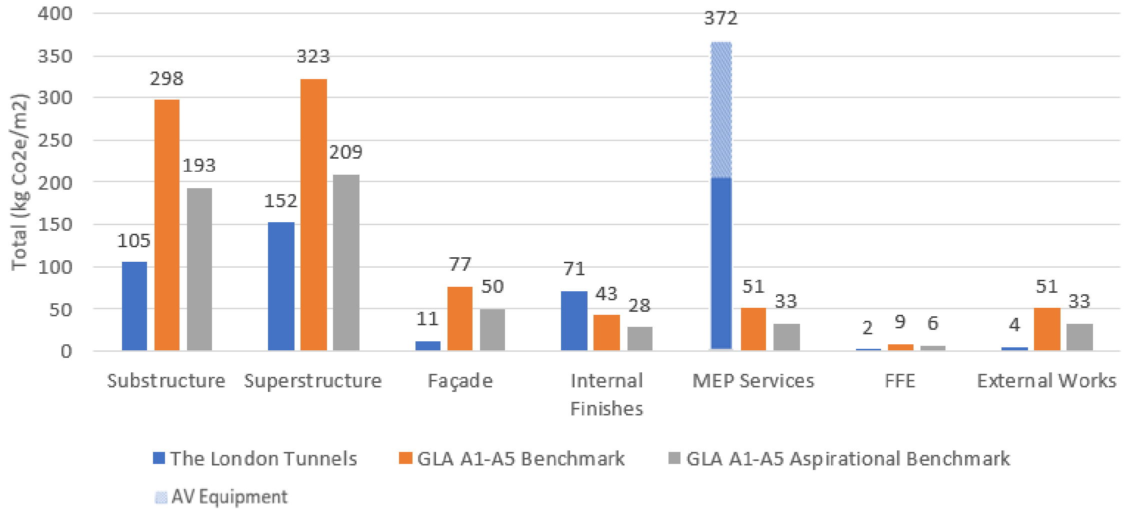

Figure 6-5 – Upfront Carbon (A1-A5) of The London Tunnels Compared to a Typical Retail Development

Figure 6-5 and Figure 6-6 show a breakdown of each building element's embodied carbon in comparison with a typical retail development in London (typical element % contributions were extracted from the GLA Guidance (March 2022)). Both graphs demonstrate that the substructure, superstructure, façade, FFE & external works are performing better than the GLA aspirational benchmarks which is likely due to the retention of the existing structure. The internal finishes and MEP services are performing worse than the upfront and whole life carbon benchmarks which predominantly results from the GRC wall panelling and raised access floors throughout the Tunnels in addition to the screens & projectors proposed for MEP which contribute to approximately 22% of the total upfront carbon and 42% of the whole life carbon.

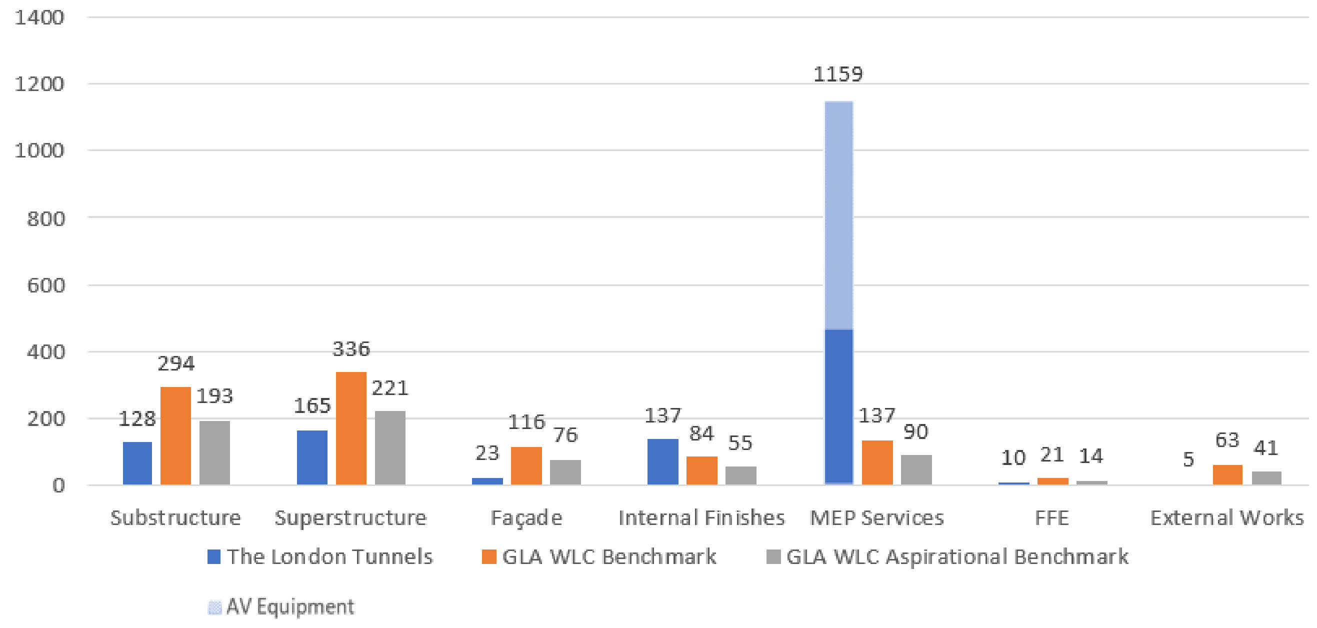

Figure 6-6 – Embodied Carbon (Modules A-C (Excluding B6 & B7; Including Sequestered Carbon)) of The London Tunnels Compared to a Typical Retail Development

Table 6-2 – Estimated WLC Emissions for Each Lifecycle Module and Building Element

	Biogenic Carbon (kg CO_2e)	A1-A3 Product Stage	A4 Transportation to Site	A5 Site Operations	B1 Use	B2 Maintenance	B3 Repair	B4 Material Replacement	B5 Refurbishment	B6 Operational Energy Use	B7 Operational Water Use	C1-C4 EOL	TOTAL kg CO_2e	Module D
1 Substructure	0	1,032,891	37,696	48,929	0	11,195	2,799	0	0	0	0	223,881	1,357,392	(9,164,771)
2.1 Frame	0	218,995	7,554	10,353	0	2,369	592	0	0	0	0	12,582	252,445	(138,758)
2.2 Upper Floors	0	936,685	16,870	27,826	0	9,814	2,453	0	0	0	0	29,452	1,023,100	(393,426)
2.3 Roof	(1,626)	95,544	2,653	4,679	0	1,029	257	25,982	0	0	0	6,134	134,652	(46,586)
2.4 Stairs & Ramps	0	133,993	1,358	7,657	0	1,430	358		0	0	0	3,172	147,968	(81,043)
2.5 Ext. Walls	(3,091)	107,130	2,591	6,275	0	1,160	290	113,033	0	0	0	5,374	232,762	(57,640)
2.6 Windows & Ext. Doors	0	5,121	78	50	0	52	13	5,281	0	0	0	157	10,751	(935)
2.7. Int. Walls & Partitions	(6,573)	123,794	511	10,333	0	1,346	337	20,396	0	0	0	10,503	160,647	(47,899)
2.8 Int. Doors	(4,014)	15,932	35	-	0	160	40	16,184	0	0	0	4,458	32,794	(6,283)
3 Finishes	(10,270)	723,543	5,442	26,678	0	7,557	1,889	656,616	0	0	0	40,478	1,451,933	(628,578)
4 Fittings, furnishings & equipment	0	17,370	16	1,308	0	187	47	87,202	0	0	0	796	106,925	(68,699)
5 Services (MEP)	0	3,740,000	106,250	106,250	0	170,000	159,375	7,788,125	0	11,554,560	28,028	243,100	23,895,688	0
6 Prefabricated	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Existing Building	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Ext. works	(39,092)	40,422	171	6,875	0	0	0	0	0	0	0	40,000	48,375	(23,508)
Other or overall site construction	0	0	0	281,918	0	0	0	0	0	0	0	0	281,918	0
TOTAL kg CO_2e kg CO_2e	(64,666)	7,191,420	181,224	539,131	0	206,299	168,450	8,712,818	0	11,554,560	28,028	620,088	29,137,352	(10,658,128)

6.2 PERFORMANCE AGAINST OTHER CULTURAL DEVELOPMENTS

Although The London Tunnels has been compared against the GLA retail benchmarks (as this is the most applicable GLA benchmark available), this comparison is not necessarily the most appropriate due to the bespoke nature of the project with proposed uses as a museum & event space. As a result, TLT has also been compared to other retention focused cultural developments in London such as the Museum of London[1] and Liverpool Everyman Theatre[2], comparing both kg CO_2e/m^2 and kg CO_2e/visitor.

MUSEUM OF LONDON WEST SMITHFIELD

The regeneration of Smithfield as the London Museum represents '*a once-in-a-generation opportunity to reconceive what a museum for London can be*[3]*'.* "The ambition is to;

- Transform the existing buildings into the new Museum of London. The buildings will enable the Museum to draw 2 million visitors per year, improve accessibility, organise major exhibition and large events, increase income generation and improve access to collection on site.
- Sensitively upgrade the performance of the historic fabric in order to satisfy the environmental qualities needed for Museum purposes.
- Celebrate the historic qualities of all existing fabric by making them integral to the arrangement of functions and a part of the story telling undertaken by the Museum.
- Enable the spaces to facilitate a Museum of the 21st Century, which is more outward looking, flexible and integrated into its surrounding context and community.
- Convert the Annexe collection of buildings from former derelict storage, loading and market spaces into habitable and flexible accommodation that can be compatible with the activities of the adjacent Museum and act as a public destination in its own right
- Act as a gateway and catalyst for the City of London's proposed Culture Mile project.[4]

A Whole Life Carbon Assessment was calculated for the Museum of London (MOL) located in Farringdon, based on Stage 2 of the design process, which is proposed to be finished in 2026 (Figure 6-7). The assessment comprises of two options, option 1, part demolition, refurbishment and extension, and option 2, full demolition & new build. Option 1 was the 'chosen option' & consequently, this option has been analysed in this section of the report. It is proposed that as much of the historic existing building components are retained as far as technically possible, consequently the project would involve:

- Partial demolition, repair, and refurbishment with an extension of the existing building on site:
  - General Market: basement, ground, first floor and roof levels
  - Poultry Market: basement, ground & first floor levels
  - Annexe site: basement, ground, first, second and third floor levels
- The Engineer House at basement and ground floor levels will involve refurbishment and minor alterations to the existing building

Figure 6-7 – Image of the Proposed Museum of London

The Whole Life Carbon Assessment for the MOL was carried out in May 2022 and resulted in approximately 600 kg CO_2e/m^2 of whole life carbon. Upfront carbon was not reported at this stage. Furthermore, the façade has been based on benchmark data from previous projects with similar typologies, MEP services has been based on 'typical' benchmarks, and the finishes were also based on LETI guidance benchmarks. As per GLA guidance (March 2022) it is worth noting that these three elements alone typically contribute to approximately 32% of whole life emissions for new build retail developments. Assessment data was also more limited with regards to façade components and MEP systems in 2022 and when compared to TLT, the scope is also more limited excluding FFE & external works. Consequently, due to the combination of benchmark data and the limitations of available information it is anticipated that the carbon impact could be significantly underestimated.

LIVERPOOL EVERYMAN THEATRE

The Stirling Prize Liverpool Everyman Theatre has also published their plan to become net zero carbon. Designed by award-winning architects Haworth Tompkins, the New Everyman is a sister venue to the Liverpool Playhouse and includes a 400-seat thrust auditorium, a dedicated space to work with young people and community groups, a workspace for writers and a basement bistro, cafe and bars[5].

[1] https://londonwallwest.co.uk/wp-content/uploads/2022/05/LLW.WholeLifeCarbonReport.FINAL_.22.05.31.pdf
[2] https://www.everymanplayhouse.com/sites/default/files/Liverpool%20Everyman%20theatre%20%20-%20our%20plan%20to%20become%20zero%20carbon.pdf
[3] https://museum.london/
[4] https://www.planning2.cityoflondon.gov.uk/online-applications/files/A567CC44EF430BFAC9D559EB633ACF5E/pdf/19_01343_FULEIA-DESIGN_AND_ACCESS_STATEMENT_CHAPTER_1_PART_1-759855.pdf
[5] https://www.gardiner.com/projects/the-everyman-theatre

The theatre had completed construction in 2013 and the report is based on Stage 4 information. Due to the lack of guidance on whole life carbon in 2013 the assessment in quite basic and looks at the foundations, frame, floors, roof, external walls and MEP services of the Proposed Development which, when compared to TLT excludes stairs & ramps, finishes, internal partitions, internal doors, FFE, external works & construction site operations ('other'/A5 emissions). These elements combined would typically contribute to minimum 15% of whole life emissions for a typical new build retail development (based on GLA guidance March 2022). It should be noted that similarly to the MOL, this report also only focuses on whole life carbon emissions.

Figure 6-8 - Image of the Liverpool Everyman Theatre

The limitations of each should be considered when comparing the carbon results & features of each development observed in

Table 6-3.

As shown in the table all cultural projects presented below have a calculated WLC greater than the current GLA benchmarks for retail areas. When the calculated WLC is divided by the expected capacity over the lifetime of the development the whole life carbon per visitor is significantly lower within The London Tunnels than both the MOL and the Liverpool Everyman.

Table 6-3 – Comparison of Features of Each Development

	The London Tunnels	Museum of London	Liverpool Everyman Theatre
Year	2029	2026	2013
Size (m^2 GIA)	10,652	49,996	4,690
Visitors/year	2,000,000	2,000,000	120,000
WLC total (t CO_2e)	17,555	29,997	4,845
WLC/m2 (kg CO_2e)	1,652	600	1,033
WLC/visitor (g CO_2e) 60 years	146	250	670

7 OPPORTUNITIES FOR REDUCTION

Opportunities for further reducing WLC will be further explored at later design stages. These alternative design ideas will require market assessment and cost consultant review before being considered for adoption. Key opportunities for further reductions from each design discipline are considered below.

7.1 DESIGNING FOR LONGEVITY, ADAPTABILITY & FLEXIBILITY

The Proposed Development has ensured that the principles of Circular Economy are embedded into the design of the project by ensuring the design is flexible and adaptable, therefore increasing the building's lifecycle. The layered design of the building enables independent layers to be upgraded or replaced. This will reduce the need for the building/elements to be demolished should it need to, for example, be upgraded/replaced, change use types or accommodate a different number of tenants, consequently reducing the carbon implications from these scenarios. Furthermore, any waste that is generated during the construction, operation, maintenance, and refurbishment/de-construction of the project in the future has been reduced as much as possible.

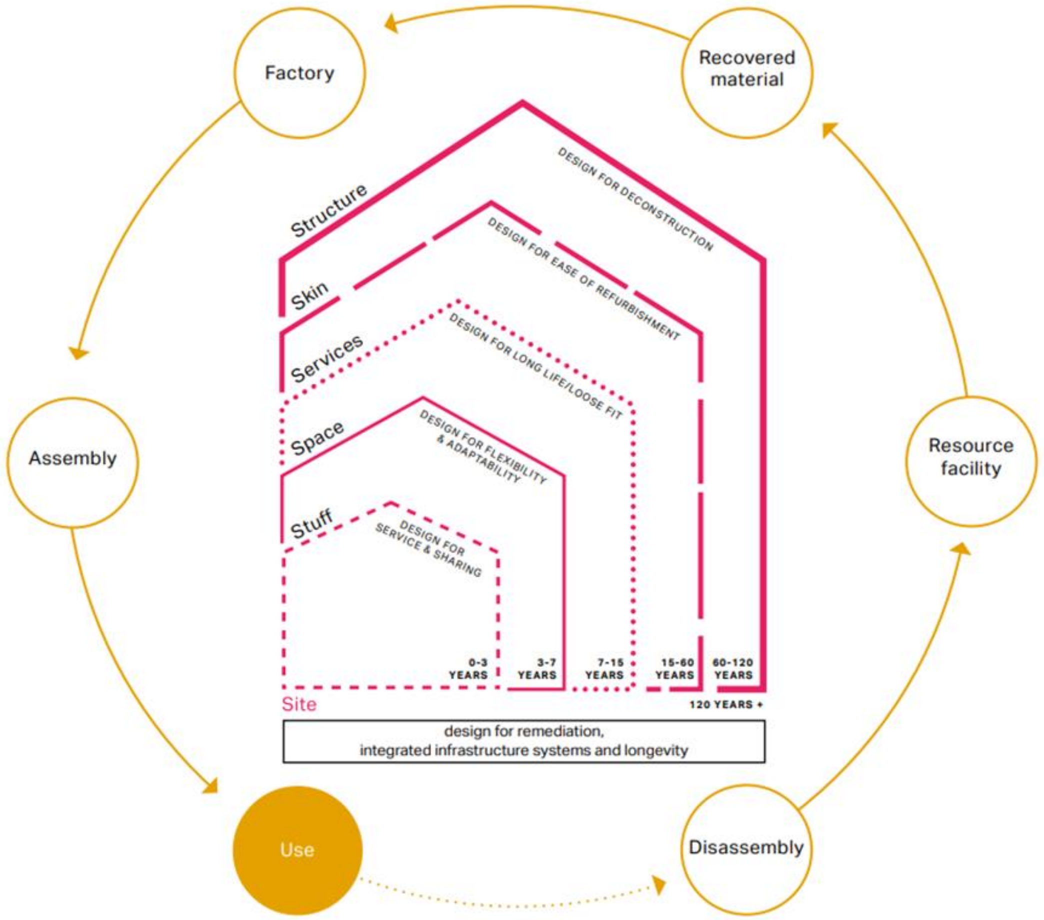

Figure 7-1 – 'Building in Layers' Diagram

7.2 DESIGNING FOR MATERIAL EFFICIENCY & MAXIMISING RECYCLED CONTENT

A Circular Economy Workshop was held with the Design Team, during which material efficiency was discussed. This topic is a priority for the Design Team and one of the key considerations during detailed design. Potential measures for reducing the material demand and for designing out waste has been and will be further explored by all key design team disciplines at each design stage. Material efficiency seeks to optimise the use of materials within building design, procurement, construction, maintenance, and end of life; with the aim being to reduce the quantities of new materials used in the development. It is anticipated that at least an average of 20% or more of the material used in the development should contain reused or/and recycled content by value. Using products with recycled materials can significantly reduce the embodied carbon of a building in comparison with using virgin materials.

7.3 RESPONSIBLE SOURCING & SPECIFICATION OF MATERIALS

The responsible sourcing of materials will be a key consideration in the selection of suppliers. A Sustainable Procurement Strategy should be produced for the Proposed Development prior to commencement of construction to control this aspect. Materials from suppliers who participate in responsible sourcing schemes such as the BRE's BES 6001:2008 Responsible Sourcing Standard will be prioritised.

All timber specified will be sourced from schemes supported by the Central Point of Expertise for Timber Procurement such as Forest Stewardship Council (FSC) accreditation–which ensures that the harvest of timber and non-timber products maintains the forest's ecology and its long-term viability.

Where viable the Design Team will specify materials that are grown or made locally. Likewise, the appointed contractor will be asked to prioritise local sourcing of materials.

The specific design of a product/material can have a significant impact on carbon emissions at the product stage (A1-A3). This is due to the components of the products/material requiring intense carbon treatment in addition to their transportation prior to fabrication. This means that the embodied carbon of the same product/material by different manufacturers will have different carbon implications. With the aim of tackling this issue EPDs which align with the exact product and/or material specification or the most applicable similar product were used throughout the WLC Assessment.

7.4 DESIGNING FOR RE-USE & RECOVERY

Building information will be stored by X to allow for end-of-life strategy, future reuse, disassembly, and waste reduction/avoidance. The recovered materials have been accounted for in the WLC Assessment.

7.5 REDUCE/REUSE/RECYCLING OF MATERIALS

The Design Team are committed to reducing reusing and using recycled materials as much as possible. it is anticipated that at later design stages material databases will be explored to determine the feasibility for using various reuse/recycled materials within the Proposed Development.

7.6 ENERGY STRATEGY

As can be observed in the Energy Strategy, the energy demand of the Proposed Development has followed the London Plan Energy Hierarchy (BE LEAN – BE CLEAN – BE GREEN – BE SEEN). Moreover, a 'fabric first' approach was considered to reduce energy demand and carbon emissions, with the aim of meeting the GLA's carbon reduction targets as per the regional planning policy.

7.7 MINIMISING QUANTITIES OF OTHER MATERIALS

During the construction stage the Principal Contractor should be required to set targets for energy and water used on site and ensure measures are put in place to minimise consumption of these resources. These could consist of:

- Low carbon energy sources used during construction phase (renewable sources of energy and offset of main utilities); and
- Use of highly efficient plant and battery power energy storage.

7.8 OPPORTUNITIES FOR REDUCTION SUMMARY

A summary of the future opportunities for reduction at later design stages can be observed in Figure 7-2. Note these are preliminary estimated reductions which are subject to programme and cost assessments in addition, should a detailed assessment be carried out of each considering a holistic approach from disciplines, these figures may vary. These are ideas which may/may not be adopted.

7.8.1 STRUCTURAL ENGINEERING

As the design progresses it is anticipated that future opportunities for reduction will be further explored and, where feasible, incorporated into the design of the Proposed Development.

- Timber structure;
- Reduction of superstructure PT slab thickness; and
- Reused steel sections in L02 gallery.

Other design opportunities that support both the Circularity & WLC of the Proposed Development (as specified in the Structural Report) include:

- Develop the concept to provide flexible space that can extend the life of the building and enhance the building users' experience;
- Design structures economically to minimise embodied carbon;
- Optimise loading criteria - no overdesign
- Specify high, but responsible, levels of recycled material content (structural steelwork, reinforcement, recycled aggregates, cement replacement) and low impact materials; and
- Consider future demolition and recycling opportunities.

7.8.2 MEP ENGINEERING

During the next design stage attention will be given to further reduce the operational carbon by investigating and assessing a number of improvements:

- Reduced AV provision
- Non-metallic ductwork
- Alternative chilled ceilings

The savings from these can be observed in Figure 7-2.

7.8.3 FAÇADE ENGINEERING

Several design optimisations related to the system design and materiality of the components will be identified to be further explored in the following stages which may contribute to the reduction of carbon of the building envelope.

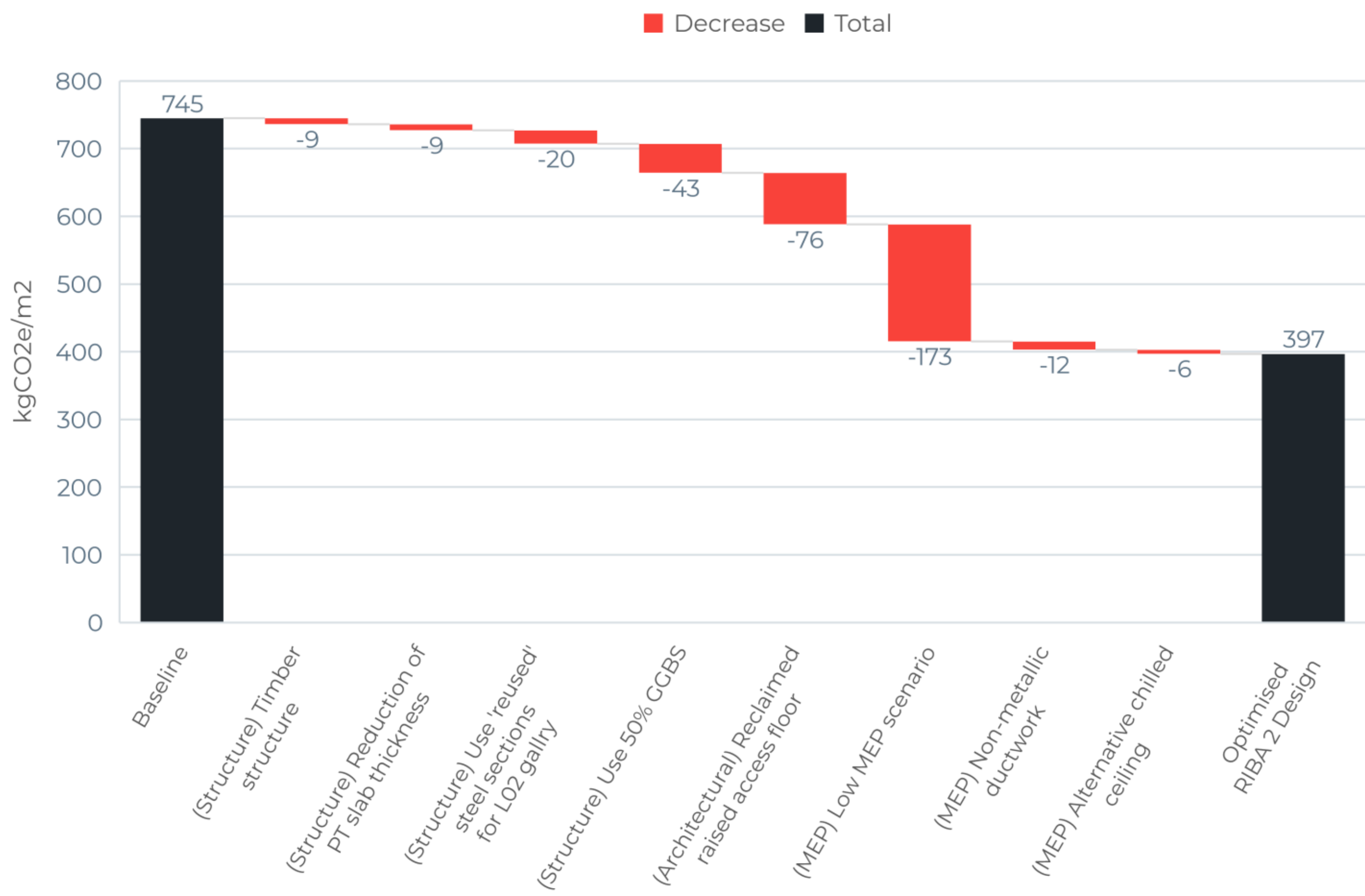

Figure 7-2 – Future Opportunities for Reduction (A1-A5)

8 CONCLUSION

This report has set out the Whole Life Carbon emissions estimated for the Proposed Development, completed following the GLA's Whole Life-Cycle Carbon Assessment Guidance.

Three scenarios have been considered to include for current design development and future potential scenarios that may be included in the CAT B design. These are as follows:

- **Low Scenario**: the baseline-low case scenario represents the base building CAT A design where the building operates with anticipated occupancy and opening hours but there is no energy intensive audio-visual equipment installed.
- **Medium Scenario**: For the medium Scenario, the AV system is assumed to be mostly projectors with some screens, equivalent to roughly 50% AV coverage of the high scenario. This scenario lines up with the Medium Scenario in the Be Seen energy analysis.
- **High Scenario**: the high scenario is based on anticipated occupancy and opening hours with a higher proportion of the Tunnels containing AV equipment. The AV system in this case is assumed to be mostly LED screens with some projectors. This scenario lines up with the High and Worst Scenario in the Be Seen energy analysis.

Of the three scenarios presented both the medium and low scenarios would result in lower upfront carbon figures when compared to the GLA benchmark, with the GLA whole life carbon benchmark being exceeded for both the medium and high scenarios. The GLA aspirational benchmarks for both upfront and whole life carbon emissions would also be exceeded for the three scenarios.

The medium scenario has been proposed throughout this report, the Whole Life Carbon for this scenario is higher than the GLA benchmark of <1,050 for retail buildings. Modules A1-A5 result in 745 kg CO_2e/m^2 which is lower than the GLA benchmark of <850. Modules B & C are estimated to produce 914 kg CO_2e/m^2 which is higher than the GLA benchmark whilst, although not included in the WLC figure, B6 & B7 are estimated to produce 11,583 t CO_2e which were measured in line with the TM54 methodology and using the latest SAP10 carbon factor over a 60-year period whilst B7 was assessed by a Public Health Engineer. It should be noted that although The London Tunnels has been compared against the GLA retail benchmarks, this comparison is not necessarily the most appropriate due to the bespoke nature of the project with proposed uses as a museum & event space.

The efficient use of materials in addition to designing out waste throughout the design and construction process has led to significant reductions in embodied emissions which can be observed throughout this report. The B4 stage (replacement) is the largest contributor to lifecycle stage emissions accounting for approximately 50% of WLC emissions with A1-A3 materials being the second largest contributor to this.

The obtention and use of the product specific EPDs should be prioritised for the proposed construction materials to be able to optimally quantify and manage the WLC of the Proposed Development.

In accordance with the GLA guidance, it is anticipated that an 'As Built' Assessment will be required at Post-Construction Stage 5/6 (upon commencement of RIBA Stage 6, prior to building handover).

Appendix A

TABLE COMPARING VARIOUS STRUCTURAL FRAME & FLOOR OPTIONS FOR FURNIVAL STREET

Frame	Floor	Spec	ST depth (deck depth) mm	Span mm	Weight kN/m²	Notes	Construction	Flexibility	Fire	Pros	Cons
RC Frame (1.9kN/m²)	PT Slab	Lightly reinforced concrete slab with 15.7mm tendons grouted in ducts.	350	9,500	8.75	Span and depth shown are for a 10kPa floor load.	Slow wet trades required + a specialist PT contractor.	Long spans with fewer columns can be achieved. Thinner slabs than RC. Flat slab design ie. flat soffit. Large openings can be designed.	Inherent fire resistance up to 240 mins.	**Min. structural depth & embodied carbon solution.** Max. flexibility with longer spans and flat soffit. No beams are required. Lighter than RC	Heavy, but lighter than RC with less concrete required. Larger foundations. Slower construction.
	RC Slab	Reinforced concrete slab with 25% GGBS or similar.	350	8,000	8.75	Span and depth shown are for a 10kPa floor load. Longer edge spans will require down-stand beam or additional column	Relatively slow wet trade.	Relatively long spans can be achieved. Most flexible to post drilled holes. Large openings can be designed in.	Inherent fire resistance up to 240 mins.	Only one contractor needed to build entire frame. Less embodied carbon than steel. Shallow ST depth and flexible flat soffit.	Very heavy. Still high embodied carbon in concrete, Heaviest foundations. Shorter spans (or more beams/columns). Slower construction. Large openings must be designed in.
Steel Frame (0.85kN/m² – heavy frame to achieve min. structural depth)	130MD	Comflor 60, 1.2mm 130mm thick slab, A252 (A393 for 10kPa). UC356 secondary. 10mm Bottom plate or asymmetric steel required. (0.15kN/m2) or EA 200x100, 400mm length @ 500mm c/c (0.15kPA)	375 (130)	Deck ~3500. Secondaries = 9,500.	2.5	No composite action - too deep if deck on top of beam (460mm). Too deep if 540mm deep cell beams are spec'd. Diaphragm using dowel bars through steel.	Slower as it requires the steel deck to be installed by one trade followed by the reinforcement and concrete by the follow-on trade.	Holes up to a certain size can be core drilled following installation. Larger holes require trimming. Efficient design requires combined structure & services zone, not possible here.	Inherent fire resistance up to 60 mins. Additional protection would be required for higher rated areas or 150mm thick slab. Steel requires intumescent.	Relatively lightweight. Lighter/smaller foundations. Longer steel spans (but deeper). Relatively fast construction	Relatively heavy steel option. Deep structural build-up to achieve composite design or heavy steels needed for shallow ST buildup. Min. depth solution inefficient. Additional fire protection required.
	Slimdek	Comflor 210, 300mm thick slab, 1.25mm deck, UC356 secondary. 10mm Bottom plate or asymmetric steel required. (0.15kPA).	375 (300)	~3000 Secondaries = 9,500	3.19	No composite action Diaphragm using dowel bars through steel. Beam depth shown for 10kPa floor load.	Slower as it requires the steel deck to be installed by one trade followed by the reinforcement and concrete by the follow-on trade.	Holes up to a certain size can be core drilled following installation. Larger holes require trimming.	Inherent fire resistance up to 120 mins. Steel requires intumescent.	Relatively fast construction. More refined system compared with 130MD option. Flat Soffit.	Proprietary system. Relatively heavy for steel. High embodied carbon. Min. depth solution inefficient. Additional fire protection required.
	Hollowcore Precast	150mm Bison Hollowcore. UC356 secondary. Needs shelf angles or 10mm bottom plate to reduce depth. Or EA 200x100, 400mm length @ 500mm c/c (0.15kPA). Might require 50mm ST topping C30 concrete.	375 (200)	~3000 Secondaries = 9,500	3.675	No composite action. Diaphragm using dowel bars and infill concrete. Beam depth shown for 10kPa floor load.	Fast as the panels are made off site and can be craned into position. Tying decks through beams will slow construction and require wet trade.	Only small holes (65mm) can be drilled on site at core locations. Drilling through wires requires detailed back analysis following installation. Larger holes require trimming and have to be considered in the design stage.	Inherent fire resistance up to 60 mins. Additional protection would be required for higher rated areas. Steel requires intumescent.	Faster construction. Minimal wet trades. Flat Soffit.	Proprietary system. Relatively heavy for steel. High embodied carbon. Min. depth solution inefficient. Additional fire protection required.

Frame	Floor	Spec	ST depth (deck depth) mm	Span mm	Weight kN/m²	Notes	Construction	Flexibility	Fire	Pros	Cons
	CLT	160mm CLT with 20mm dry screen board. UC356 secondary. EA 200x100, 400mm length @ 500mm c/c (0.15kPA) or 10mm Bottom plate or asymmetric steel required.	375 (160)	4000 Secondaries = 9,500	0.8	No composite action. Diaphragm action from screwing though timber. Better to put on top flange = 490mm depth. Secondary beams could be Glullam or LVL. Columns could be Glulam or LVL. Beam depth shown for 10kPa floor load.	Fast, as panels are made off site and can be craned into location. Significantly quicker than other options + no wet trades. Needs max area to justify long shipping distance.	Service penetrations can be made off site so long as services are coordinated at the time of fabrication. It is also possible to make them on site subject to location and size.	Medium performance with inherent char performance of timber members. The thickness of CLT panel determines the fire rating but soffit fire protection boarding will be required. Building >18m requires additional Auto-extinguishing checks. Steel requires intumescent.	Very fast construction, Very lightweight (lighter foundations) and low embodied carbon.	Additional acoustic and fire provisions are needed to meet design requirements. Min. depth solution is inefficient. Additional fire protection required for both timber and steel. Fire testing may be required to justify >18m building. Stiff deck for diaphragm action and continuity for robustness hard to achieve.

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