London Wall West

Whole Life Carbon Assessment

May 2022

CITY OF LONDON

Contents

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Glossary

Term	Definition
Embodied Carbon	The carbon cost of delivering the development from extraction of raw materials through to completion of the project on site, replacement through the life of the building and deconstruction at the end of the building's life.
Operational Carbon	The carbon cost of operating the development over the lifecycle of the building.
Whole Lifecycle Carbon	The combination embodied carbon and operational carbon impacts over a defined building lifecycle
COIL	Certificate of Immunity from Listing
HE	Historic England
LWW	London Wall West
MOL	Museum of London
BCO	British Council for Offices
EPC	Energy Performance Certificate
DEC	Display Energy Certificate
$kgCO_2e$	Kilograms of carbon dioxide (equivalent) – This is a measure used to enable comparison of options considering impacts on climate change. Relevant data, for example energy demands, greenhouse gas emissions etc. are converted into equivalent measures of CO_2 for easy comparison.
CIBSE	Chartered Institution of Building Services Engineers
CAZ	Central Activity Zone

Executive Summary

This report has been commissioned by the City of London Corporation for consultation with stakeholders during the pre-application stage for the London Wall West Development. It provides a qualitative assessment of the existing buildings and a quantitative study of the carbon impacts of two development scenarios (1) which retains some existing building fabric and creates new development through new and retained building fabric; and (2) full demolition of the site and erection of new buildings.

These two development options have been prepared during design development and the preferred scheme is still subject to further design development in advance of the submission of a planning application, alongside a full suite of application documents and relevant assessments.

The analysis concludes that retaining existing building fabric does not achieve the most sustainable outcome for this transformative and strategic site. It also concludes that it is not possible to undertake a "light touch" refurbishment due to inherent safety concerns with the existing buildings, that make them unsuitable for retention and adaption, and are therefore not feasible for anything other than a short-term solution.

It is recognised in this report that the preferred redevelopment option will require more carbon spend in absolute terms. A Whole Life Carbon Assessment has been prepared to compare the two options, on a $kgCO_2e/m^2$ basis, the assessment concludes that the redevelopment option would perform 10% better than the retention option, which would still require a significant carbon investment.

The analysis carried out in this report concludes that retaining the existing buildings is not appropriate in this instance and it is prepared to make a carbon investment in these buildings to unlock the greatest amount of strategic and public benefits from the site to achieve its aspirations for London Wall West.

This report has been prepared in co-ordination with a multi-disciplinary team, comprising:

BURO HAPPOLD	DS+R	SHEPPARD ROBSON	GERALDEVE
Sustainability consultants	Lead designers	Collaborating architect	Planning consultants

1. Introduction

This report has been commissioned by the City of London Corporation for consultation with stakeholders during the pre-application stage for the London Wall West Development. The proposals are subject to further development, and it should be noted that the final proposals will be set out in full as part of a future application for planning permission.

The subject site is located at the junction of London Wall and Aldersgate Street, in the City of London, and comprises two principal buildings, the Museum of London and Bastion House. The Museum contains public exhibition galleries on two levels, with an upper level of administrative and technical spaces and an education wing to the northwest. Public entry is at first floor level, via the City's high-level walkways. A basement level contains storage space and workshops, with a sub-basement housing a car park, service ramp and plant. Bastion House, latterly known as 140 London Wall, is a 14-storey office building, developed in tandem with the Museum. It sits above the eastern wing of the Museum, with its structure extending through the Museum, so that the two buildings are effectively interlocked. Both buildings were designed by the architectural practice of Powell Moya & Partners (structural engineer: Charles Weiss & Partners) and constructed (by contractor G.E.Wallis) in 1971-76.

The site is under review as an important development opportunity as The Museum of London is planned to be relocated to West Smithfield in 2025, with the current Museum closing its doors to the public at the end of 2022, and with vacant possession of Bastion House in 2023. The existing buildings that will become vacant are approaching 50 years of operational life and as will be explained in this report are compromised and therefore require investment through development to ensure they are fit for purpose for the future. Not least, Bastion House no longer provides office accommodation that meets the requirements of office tenants in 21st century, and the Museum building cannot easily be adapted for another use.

This brownfield site has the potential for a significant level of investment for improvements to better optimise the site and ensure it can bring benefit to the Square Mile. The site has the potential to deliver significant benefits to the City of London, residents and workers in the area and wider stakeholders.

Having regard to the Development Plan, developments should be designed to promote circular economy principles throughout the life cycle of a building. Specifically, London Plan Policy SI2 requires major developments to prepare whole life carbon assessments, Policy SI7 ('Reducing waste and supporting the circular economy') sets out a series of circular economy principles that major development proposals are expected to follow. Emerging City Plan 2036 Policy S16 sets out the City's support for Circular Economy principles. It is therefore widely expected that proposals that involve substantial demolition and/ or part demolition should demonstrate that it is not feasible to retain and improve the existing buildings.

This study sets out a qualitative assessment and analysis of the existing buildings to understand what types of development could be brought forward, including potential reuse and redevelopment options and considers the impact of these options on carbon emissions, drawing reference from planning policy and recent guidance from the GLA on Whole Life Carbon and Circular Economy (WLC Assessments London Plan Guidance and Circular Economy London Plan Guidance).

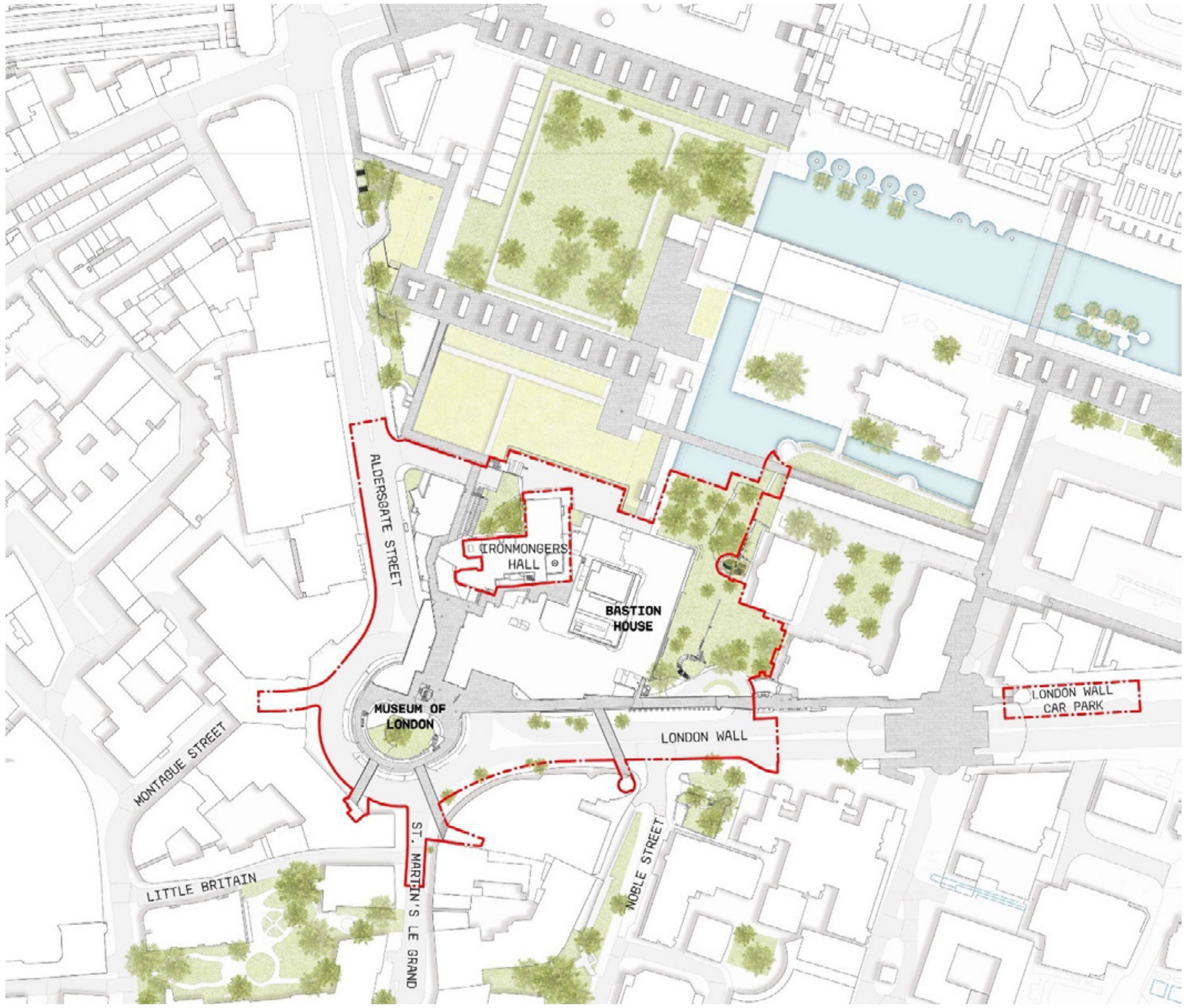


Figure 1—1 – Subject Site (Indicative redline boundary that is subject to change)

2. Summary of the Report

This report sets out an appraisal for retention options compared to the new build options for the site. This includes consideration of a light touch refurbishment option (which is not considered to be feasible), a part demolition/ part retention option with extensions, changes to the facades/ cladding and adaptions to the existing structure, through to a full redevelopment option. This report considers the architectural, structural and engineering feasibility of redeveloping the site along with considerations of operational and embodied carbon emissions assessment over a minimum development lifespan of 60 years.

In all instances, given the pre-application stage the proposals are at, with design proposals still to be progressed, the options are based on a number of assumptions and uncertainties which are set out throughout this report. In addition, retention options differ significantly in achievable area uplift due to structural limitations, which also has implications for the financial viability of these options.

The appraisal of the existing buildings sets out a number of critical technical challenges that limit the feasibility of a light-touch refurbishment option. On the basis that the light touch refurbishment option is not considered feasible for anything other than a short-term solution, a Whole Lifecycle Carbon Assessment has been completed for two principal options; (1) a part demolition/ part retention scheme and (2) a full redevelopment scheme. This assessment is based on an illustrative version of the proposed options based on the work done to date. This document provides an indication of direction of travel as the pre-application process evolves. A complete Whole Lifecycle Carbon Assessment will be submitted in support of the final planning application. The part demolition/part retention scheme is based on retaining a significant proportion of the substructure and existing podium structure which houses the Museum of London whilst demolishing the existing Bastion House, extending elements of the podium and delivering new buildings on the Bastion House and Rotunda. The full redevelopment scheme involves more extensive demolition, re-configuration of the road network around the site and construction of new buildings that balance the efficient use of the site with extensive new public realm.

The estimated results show that the part demolition/ part retention option is likely to have a higher Whole Life-Cycle carbon performance per square metre when compared to the full redevelopment scenario. On a per-square metre basis, the embodied carbon emissions are higher for the full redevelopment option whilst the operational carbon emissions are lower, due to improved building fabric performance and efficiency of space planning to deliver an improved façade-to-floor area ratio compared to the part demolition / part-retention scheme. The operational and embodied carbon emissions are combined over a 60-year design life to assess Whole Lifecycle Carbon Emissions[1].

When taking into account the fact that the full redevelopment option delivers more floor area than the part demolition/ part-retention scheme (using this prominent site more efficiently) the full redevelopment option would have the highest Whole Life-Cycle carbon impact in absolute terms. However, on a per-square metre basis, the Whole Lifecycle Emissions of the full redevelopment option are 10% lower compared to the part demolition/ part-retention scheme.

The carbon assessment results set out in this report have to balance against the technical challenges associated with the options discussed and the opportunities presented by each scheme.

The proposed full redevelopment option is considered to provide more extensive benefits compared to the part demolition/pert-retention scheme through high quality floorspace, highways improvements, public realm improvements, urban greening, accessibility/ permeability of the site, flexibility and future adaptability.

Accordingly, having regard to the London Plan and associated guidance in respect of the Whole life Carbon Assessments London Planning Guidance and Circular Economy Statements London Planning Guidance, this assessment has considered reuse options, and on balance having regard to the carbon analysis for both principal options and wider public benefits, it is considered that the case for full demolition can be justified in this instance.

[1] The 60 Year Lifecycle is determined by the standard analysis methodology adopted by the GLA. For new-build elements we would anticipate a longer building lifespan. The assessment methodology takes into account the differing lifecycles of each element of the building, for example internal finishes will need replacing multiple times through the lifespan of the building.

3. Relevant Planning Policies

The following section of the report briefly highlights key relevant planning policies that consider development on existing sites and the balance of whole life cycle carbon assessment for site options.

Policy SI2 of the London Plan (2021) relates to the minimisation of greenhouse gases within major developments across London. Developments are required to minimise their energy demand and production by using less energy and managing demand during operation ('Be Lean'), exploiting local energy resources and supplying energy sufficiently and cleanly ('Be Clean'), whilst maximising opportunities for renewable energy by producing, storing and using renewable energy on site. Part F of Policy SI2 states that 'development proposals referable to the Mayor should calculate whole lifecycle carbon emissions through a nationally recognised Whole Life-Cycle Carbon Assessment and demonstrate actions taken to reduce life-cycle carbon emissions.'

Policy SI7 of the London Plan (2021) relates to the reduction of waste and the increase of re-usable materials to support the circular economy of major developments. Part B of Policy SI7 notes that 'referable applications should promote circular economy outcomes and aim to be net zero-waste.' Within the Circular Economy Statement, details of how demolition and remediation materials will be re-used and recycled should be set out, as well how development proposals' design and construction will reduce material demands and enable building materials, components, and products to be disassembled and re-used at the end of their useful life. In March 2022, the GLA published the Whole Life Cycle Assessment and Circular Economy Statement London Planning Guidance which provides additional information on requirements for planning applications.

Core Strategic Policy CS15 of the City of London's Local Plan (2015) requires all development proposals to develop the highest feasible sustainability standards in the design, construction, operation and 'end of life' phases of development. Part 3 of Policy CS15 notes that large scale demolition should be avoided 'through the re-use of existing buildings or their main structures, and minimising the disruption to businesses and residents, using sustainably sourced materials and conserving water resources.'

Strategic Policy CS16 of the City's Draft Local Plan (2021) relates to overall strategic management of waste at all stages of the development cycle. By applying key circular economy principles and applying the waste hierarchy principles, the City can ensure waste is designed out and embodied carbon can be retained. Policy CE1 of the City's Draft Local Plan (2021) states that development should be designed to promote circular economy principles throughout the life cycle of the building. This can be achieved by the 're-use and refurbishment of existing buildings, structures and materials to reduce reliance on virgin resources and retain embodied carbon.'

4. Existing Site & Buildings Analysis

This section of the report conducts an analysis and assessment of the various aspects of the existing buildings: heritage, public realm, architectural, structural & building services engineering, including energy performance, materials and fire considerations. This analysis examines a range of technical issues including both current usage and the potential for future changes of use.

4.1 Architectural and Heritage constraints to the site

4.1.1 Historic England and Potential for Listing

A joint Certificate of Immunity from Listing (COIL) was issued for the Museum of London and Bastion House in July 2019 (List UID: 1464340). In order to make their assessment, Historic England (HE) considered the two buildings against the Principles of Selection for Listed Buildings (November 2018) and other relevant guidance. The 2019 COIL was a renewal of a 2015 COIL; it expires on 20 August 2024.

In relation to the Museum of London HE give the following key reasons:

- It does not compare to other listed buildings of a similar type and date and is not of the same quality as the listed examples of Powell and Moya's work;
- It is very altered – in particular the original layout, fixtures and fittings;
- Its limited architectural interest reduces its historic significance as the Capital's museum;
- Its group value with the Grade II Barbican and Scheduled Monument (London Wall) is also low due to its low degree of architectural and historic interest in its own right.

In relation to Bastion House, HE state that:

- Its architecture has "a restrained form and treatment lacking the innovation and quality of listed examples of its type and date";
- It has historic interest for its part in London's post-WWII masterplan, in which a network of highwalks was envisaged across the City, with vehicular traffic below, however this interest is limited due to the erosion of those aspirations in the redevelopment of London Wall;
- Like the Museum, its group value with the Grade II Barbican and Scheduled Monument (London Wall) is low due to its own low degree of architectural and historic interest.

The Museum and Bastion House were designed at lower levels to "plug into" the Barbican network of highwalks, and to new parts of that network as it was extended. This aspect of both buildings has a degree of historic interest, however, because that wider masterplan was never realised, these buildings have resulted in an uninviting and inaccessible southern edge to the Barbican Estate, significantly reducing the minor historic interest that this element possesses. The Museum Rotunda has a fortress like presence at ground level, which was deliberate, but which has a highly negative impact on the experience of the townscape in its current context. Similarly, there is a notable opportunity to improve the existing setting of the Scheduled

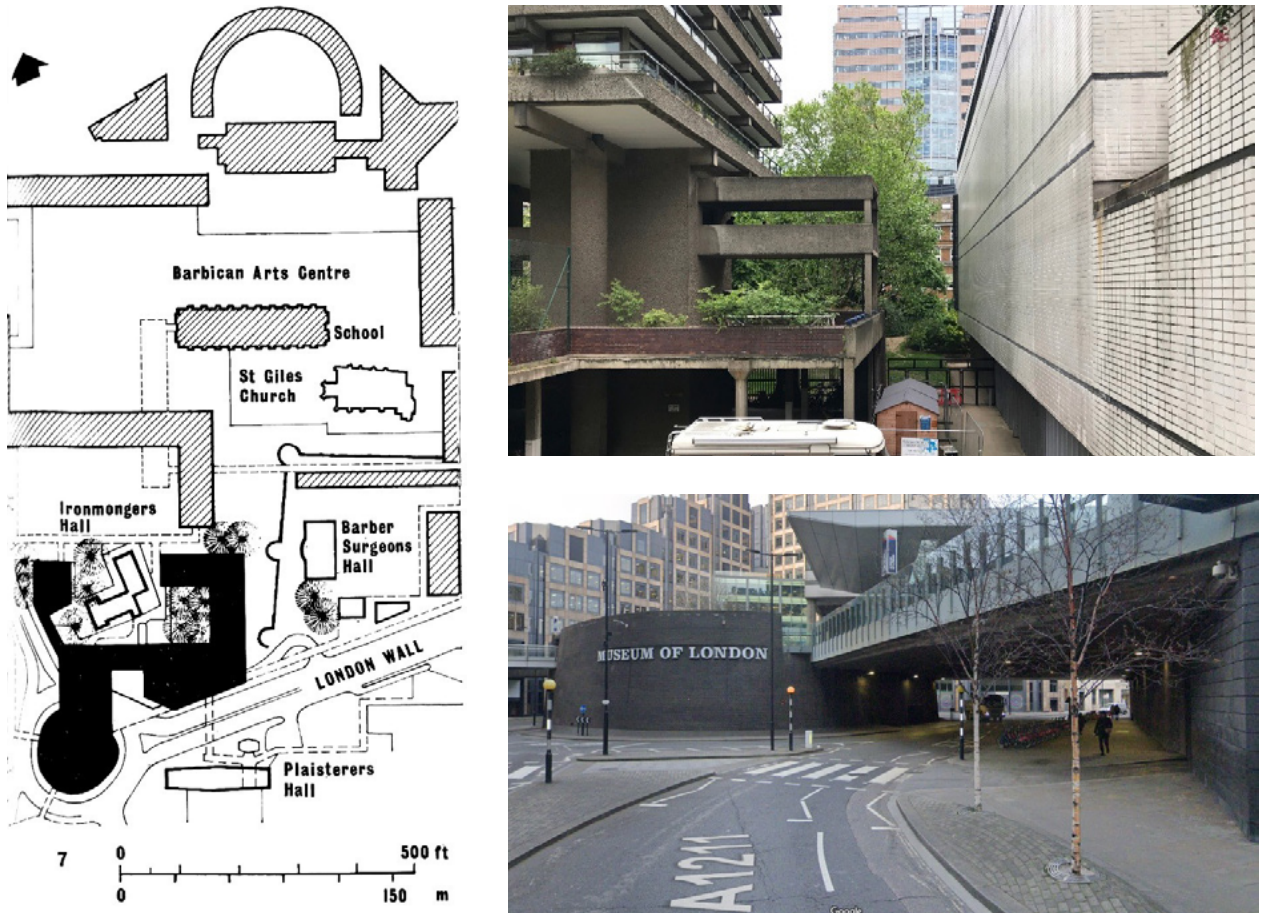


Figure 4—1 - The exiting site

Monument of the London Wall which goes well beyond the existing high-level window currently provided by the Museum. The Museum of London currently forms an imposing setting to the Scheduled Monument of the London Wall which could be greatly enhanced.

As HE note in the COIL, internally the Museum is significantly altered and "no longer has its clarity of design and flow of space".

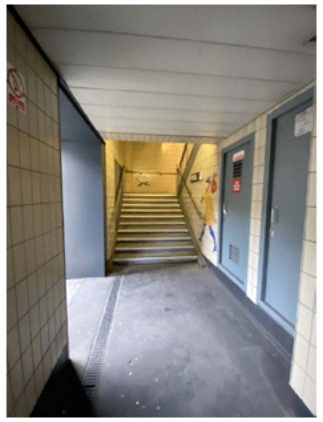
Historic England find that Bastion House "lacks innovation", noting that "the stringent design principles for the London Wall offices laid down by the local authority did not give the architects a free reign". It goes on to contrast it to listed office buildings of the period, concluding that "Bastion House appears mundane and perhaps old-fashioned in its treatment; overall it lacks the architectural quality and innovation so clearly expressed by listed examples and should not be added to the List."

In conclusion, the heritage significance of the Museum of London and Bastion House is considered to be limited, as HE agree. Additionally, the designs of the lower levels, which form an aspect of their limited historic interest, have a negative effect on the townscape character of the locality and inhibit opportunities for improving access to, and appreciation of, neighbouring designated heritage assets of the London Wall (Scheduled Monument) and Barbican Estate (Grade II buildings and Grade II* landscape).

4. Existing Site & Buildings Analysis

4.1.2 Existing Public Realm

At street level the existing buildings do not create an enticing public realm, approach or access. The Museum Rotunda has a fortress like presence at ground level, which has a highly negative impact on the experience of the townscape in its current context as described above. None of the other facades have any active interface; they are either solid blank walls or are voids overlooking basement service areas. Activation is inhibited by any ground floor areas that are not voids being raised above the street level. Service vehicles access the building lower ground floor (along with a secondary entrance to Bastion House) to the east of the site is via a slip road off London Wall, which cuts off access to a portion of the extant Historic City Wall, a Scheduled Monument.



The main entrances to the Museum of London and Bastion House are at Highwalk level, and access to this is unintuitive and via a series of staircases/lifts/escalators, with the main access to the complex on the south side of London Wall. However, as described in the heritage assessment above, the highwalks that are part of the site are an important feature of the pedestrian infrastructure, particularly as they provide access through the site to the Barbican estate highwalks connecting currently to the east along London Wall, and to the North at the South-West corner of Barbican estate adjacent to Aldersgate Street.

4.1.3 Spatial assessment

Bastion House
Based on its current use as an office tower, the floor-to-floor heights in Bastion House are very low and the column spacing is very restrictive. The existing floor-to-ceiling heights in Bastion House are approximately 2.54m. This limits natural lighting to the depth of the floor plate and creates undesirable office accommodation. Guidance from the British Council for Offices (BCO) recommends that for refurbishments 2.45m to 2.8m floor-to-ceiling heights are acceptable in some circumstances whilst for new-build offices with deep plan floor plates, floor-to-ceiling heights should be 2.8m to 3.2m.

The existing structural column grids (the existing spacing between the columns) in Bastion House are at 5.1m x 5m and 5.1m x 4.4m with a worst-case pinch-point adjacent to the existing cores of 3.2m between vertical structural elements. Guidance from the BCO recommends regular structural grids of 9m, 10.5m,12m or 15m which are larger and fit a typical office planning unit of 1.5m. The limited floor-to-ceiling height and column grid would provide constraints on incoming office tenants, making the space less attractive for office occupiers.

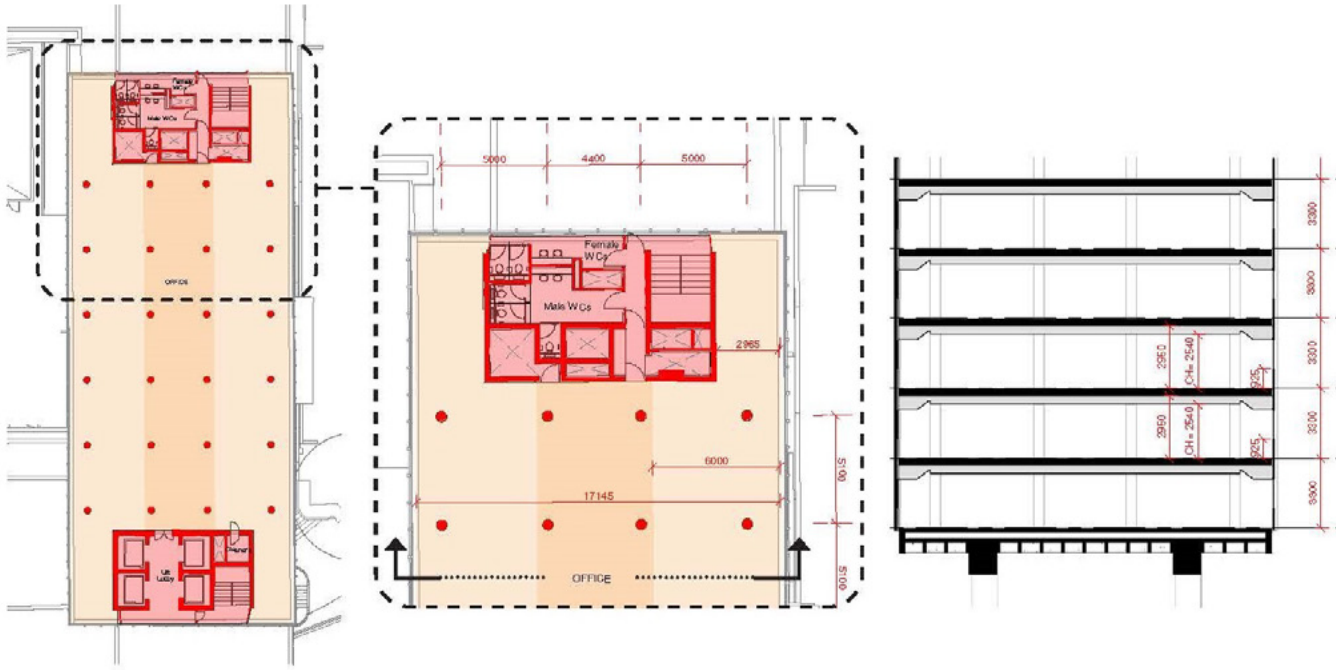


Figure 4—2 Existing typical office floor in Bastion House demonstrating constraints

Museum of London
The Museum of London building forms a podium across most of the site including below Bastion House. This is comprised of several types of space: the museum display spaces are tall double height gallery spaces with deep floorplates and limited access to daylight. This is coupled with some very low office spaces, with floor-to-floor height of 2.75m, and clear ceiling height of only 2.4m, very low by modern standards. In addition, there are back of house storage / workshops at the lower ground floor, and miscellaneous public support spaces such as the museum entry, café, shop etc. The existing Museum podium gallery façades are nearly all solid on all sides based on the black-out requirements deemed necessary in the 1970s for the museum display.

4. Existing Site & Buildings Analysis

Fire Safety
While the buildings would have been designed to fire-fighting and evacuation standards current at the time, these are significantly below what would be required to comply with today's building regulations. For example, protected lobby spaces with wheelchair refuges along with fire equipment and evacuation lifts would need to be provided to meet current requirements. While the facades of the buildings underperform in terms of their thermal performance, they also do not meet today's fire safety standards (also see the further information within the analysis of energy performance and Fire Integrity).

Services & Amenities
Within Bastion House, provision of WCs is below current standards both in terms of numbers of facilities and provision of accessible WCs. Provision of additional WCs would reduce the available office floor space for rental. Lift provision is also significantly below modern level of service as defined by BCO (British Council for Offices) standard of best practice. This limits accessibility as well as the quality of service provided to occupiers.

4.2 Engineering Feasibility

An engineering review of the existing buildings has highlighted three key challenges that would need to be addressed in any retention proposals for the site:

- Material design life
- Fire integrity
- Design for disproportionate collapse

4.2.1 Material Design Life

The original structural design calculations for the development are not available in the London Metropolitan Archive. The original calculations would have provided information on the building's structural design life. In the absence of the original brief and calculations we need to rely on what we know was good practice at the time of the building's conception and development. The scheme was designed in the late 1960s/early 1970s, construction was undertaken between 1971 and 1976. At the time, a typical building design-life for the main structure would be 50 years. Based on this Bastion House and the Museum of London are approaching the end of their design life. Of course, this doesn't mean that the building stops being usable but does mean that we can anticipate that structural and engineering issues can start to arise linked to the ageing of the structure. One such issue for reinforced concrete buildings such as Bastion House and Museum of London would be carbonation of the steel in the structure.

Carbonation is a time-dependent process of atmospheric air penetrating the concrete to reach the embedded steel bars and causing corrosion. This becomes visible as spalling concrete and rusting metal visible on the outside of exposed surfaces. The rate of carbonation is predictable and depends on the depth of concrete cover to the steel and the extent of exposure to the atmosphere. A design life of 50 years would determine such things as the depth of concrete protection to the reinforcing steel in the structure based on the anticipated rate of carbonation.

Carbonation does not occur uniformly across a structure with the process occurring faster for more exposed areas of structure.

For Bastion House, a key area of consideration for this carbonation process would be the exposed transfer structure of which sits above the podium of the Museum of London. There is a greater risk of significant carbonation in this area compared to more protected areas of both Bastion House and the Museum of London.

Figure 4—3 Bastion House Tower showing transfer structure above the podium of the Museum of London which is exposed to carbonation and at risk of disproportionate collapse.

Assessing the extent of carbonation is not straightforward in existing buildings requiring visual inspection of all areas of concrete and intrusive testing and sampling. A technical solution to resolve this issue is to apply a proprietary anti-carbonation coating, applied to inhibit further carbonation, which would require re-application every 15 years or so. Although costly, this would be potentially technically feasible subject to lease arrangements with future building occupiers.

4.2.2 Fire Integrity

Fire integrity is an important consideration in ageing buildings. Both buildings in this instance would have been designed to meet the requirements in place at the time, however fire integrity requirements continue to develop through updates to Building Regulations requirements. For existing buildings, there is generally currently no retrospective statutory requirement for them to comply with present day standards. However, in the event that the building is extended, changed to an alternative use, or, for example, the cladding to the building is replaced, remediation would need to be undertaken.

For both the Museum of London and Bastion House, one impact of this would be a requirement to add fire-protection boarding to the reinforced concrete structural members to compensate for the relatively shallow depth of concrete cover that would have been used to comply with the regulations in place in the early 1970s. This would reduce floor-to-ceiling heights in the areas where the boarding is provided. As set out in the spatial assessment (4.1.3), these heights are already low in Bastion House, and in the single storey areas of the Museum of London with 2.4m clear heights, very low.

4. Existing Site & Buildings Analysis

4.2.3 Disproportionate Collapse

Disproportionate collapse is the most significant engineering challenge for Bastion House. This term describes a mode of structural failure where loss of a supporting structural element (column, beam, wall or slab) causes a total collapse, or a significant structural collapse, that is disproportionate to the original cause. The loss of the structural element could for example be through explosion, vehicle impact or through human error in modifying the building as part of an alteration or extension to the existing structure.

Disproportionate collapse was likely to be a contributing factor in the catastrophic failure of Champlain South Tower in Miami in 2020 and famously, the Ronan Point disaster in London in 1968.

In response to Ronan Point, changes were made to the UK Building Regulations, requiring buildings to be designed with increased robustness from 1972. The original structural design calculations for the development are not available in the London Metropolitan Archive. The original calculations would have demonstrated the degree of robustness allowed for in the design. As construction of the building had commenced on site prior to introduction of the enhanced building regulations requirements it is unlikely that enhanced robustness was allowed for in the design of Bastion House. There is further evidence that this is the case from the design of the Level 3 transfer structure.

In the absence of the structural design calculations, we have completed a high-level appraisal of the structure of the buildings to look at vulnerabilities and potential mitigation. For the typical floors of both Bastion House and the Museum of London, robustness could be enhanced through additional structural strengthening works (additional vertical steel structure and bracing). However, for Bastion House, the Level 3 transfer structure would be of particular risk.

At Level 3, four significant structural columns support the tower above. Our study highlights that loss of structural integrity of any one of the four columns would likely cause a disproportionate collapse. It should be noted that a disproportionate collapse is a consequence of a disastrous occurrence such as an explosion or vehicle collision. As such, it remains as an inherent challenge to the building, however it does not mean there is an immediate risk of building collapse.

To significantly enhance robustness and address the disproportionate collapse issue at this transfer level would require the construction of a new transfer structure designed to support the upper levels. This would require a significant element of horizontal structure under the transfer deck with its own vertical columns through the podium and foundations. Along with the technical challenge of achieving this structural design, significant embodied carbon would be invested.

Whilst theoretically possible, this structural intervention would have an impact visually on the existing building and be technically, practically and economically very challenging. Our structural engineering team would not recommend this approach because of the cost, technical risk and degree of intervention required to deliver a still constrained building.. Accordingly, the challenges associated with potential disproportionate collapse which arises from the unique transfer structure and column design at Level 3 of Bastion House, means that reuse of Bastion House is not considered feasible from an engineering perspective

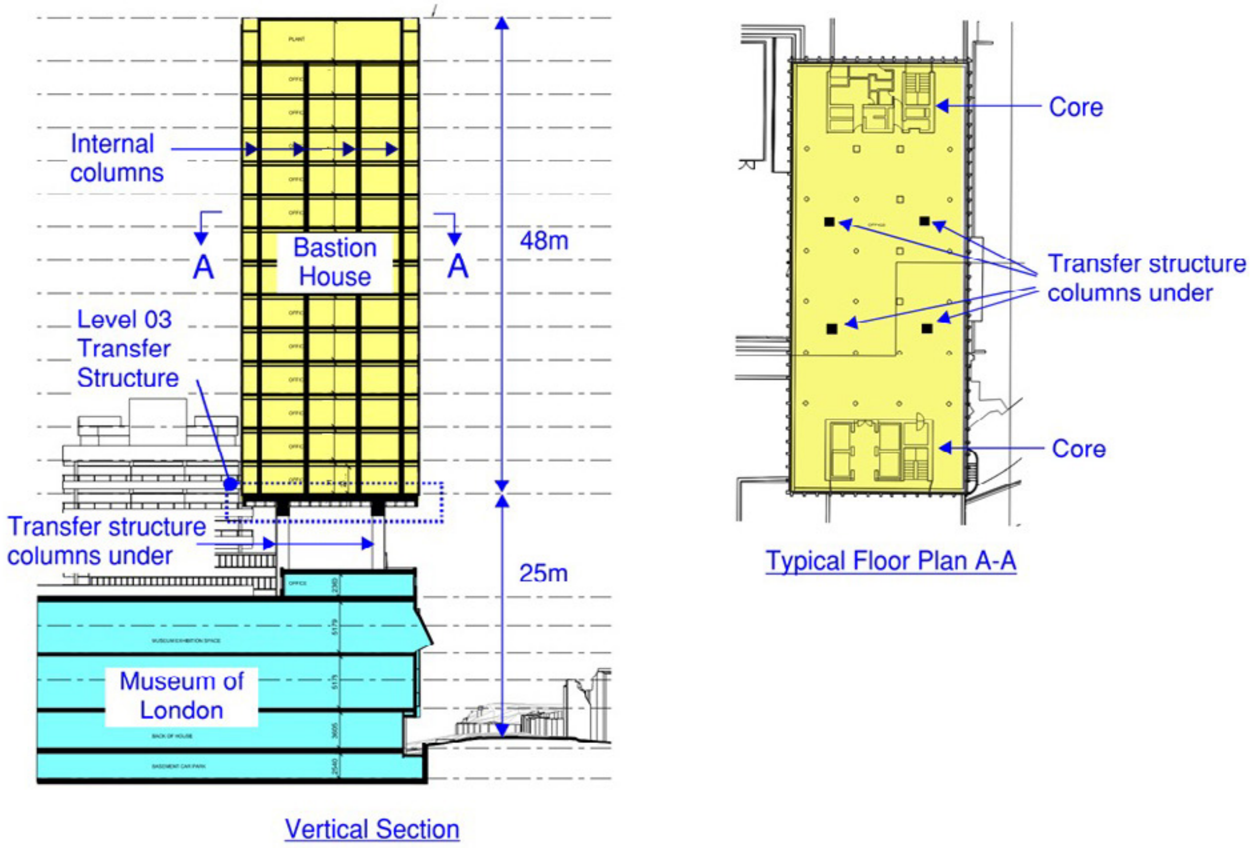


Figure 4—4 Bastion House and Museum of London Simplified Section and Plan

Having been designed and developed at the same time as Bastion House, the Museum of London building has similar issues relating to disproportionate collapse. However, as a low-rise development, the issues are less extreme than for the tower, and remediation works would be more straightforward to carry out. Albeit significant interventions such as structural strengthening works, and additional bracing may be required to resolve any inherent issues particularly if a more substantial alteration or extension was proposed.

As with most updates to building regulations, the change to the requirements for robustness were not retrospective. However, upon extension of the building or significant modification, including insertion of new voids through the structure for lifts or service risers, the building would be required to satisfy the current codes.

4.2.4 Energy and carbon performance of existing buildings

As noted in the planning policy section of this report (3) developments must examine the carbon impacts of any substantial alteration works. This next section looks at the energy performance of both Bastion House and the Museum of London as they exist today.

4. Existing Site & Buildings Analysis

Bastion House
Bastion House has a fairly typical façade build-up for a building of its period with limited insulation and single glazing. No significant upgrades to the façade have been completed in the building's lifetime. The installed building services appear to have been subject to upgrades over time, some floors have modern LED light fittings for example. Heating and cooling are understood to generally be from the Citigen district network with ancillary heating and cooling systems added over time.

As a commercially let building, Bastion House requires an Energy Performance Certificate (EPC) to be produced and provided to prospective tenants. The EPC is based on a theoretical model of the building rather than measured data for the site. The EPC is measured against a scale from A-G with A being the highest performing and G the worst. A typical new build would achieve an A rating and a C rating is stated as being typical of existing stock. Landlords are not permitted to rent buildings achieving an F or G rating to tenants from 1st April 2023. For Bastion House, an EPC was produced in June 2019. The building achieved an EPC rating of 'E'. The poor energy rating is most likely driven by the existing façade configuration which will drive high cooling demands in summer and heating demands in colder months. The EPC rating demonstrates that the building performs poorly compared to both typical building stock and new build developments and indicates that the current operational carbon performance is poor.

Museum of London
As a publicly accessible building, the Museum of London has been measuring and publishing its energy use each year through the Display Energy Certificate (DEC) scheme. The energy use is based on actual measured energy data and is measured against a scale from A to G, with A ratings being the best performing buildings and G at the bottom of the scale.

The recently published data for the Museum of London is as follows:

Year	Operational Rating		Notes
2017	G	156	
2018	G	151	
2019	F	149	
2020	G	160	Metering data from April 2019 to April 2020 so misses most of the pandemic impact
2021	E	123	Reduced operation due to pandemic

The energy performance data indicates that the existing Museum of London building performs poorly in terms of energy use which means that the current operational carbon performance is poor.

Subject to detailed energy studies, energy performance improvements to the existing Bastion House and Museum of London buildings could be delivered through significant investment in the buildings. Measures required would include façade upgrade and replacement, renewal of building services installations including heating, lighting, cooling and controls and provision of renewable energy systems. Investment on this scale would only be recommended as part of a long-term solution to the site.

4.3 Assessment of Re-use of Existing Buildings

This section of the report looks at the potential for the reuse of the existing buildings with minimal interventions. The team have sought to identify the potential for refurbishment or refurbishment and modification of the existing buildings.

4.3.1 Assessment of reuse as current functions

As described in section 4.1.3 Bastion House is currently used as office space. The building could be retained as offices in the short term but there are considerable limitations to the existing office accommodation as outlined in the preceding assessments: Floor-to-floor heights are below contemporary standards, columns have narrow spacings, poor lift provisions, outdated fire safety standards, and poor energy performance.

To attempt to address these issues would entail major interventions, renovations, and investment which would need a degree of financial return through new floorspace to be feasible. Coupled with the analysis of structural issues such as the risk of disproportionate collapse, fire integrity of the structure and potential for material issues such as carbonation it is hard to justify this as a long-term solution for the building. The extent of investment required to maintain low quality office accommodation could not be justified.

Without this level of investment, a limited cosmetic refurbishment of the interior could be completed to maintain some office use within the building in the short-term.

The Museum of London was designed to meet the specific requirements of the occupier in the 1970s and is heavily constrained in design, structural and engineering terms. The building might be reused by another cultural institution, but the accommodation would be limited by the inherent constraints of the building. The access and approach to the Museum of London building is poor and there is little natural light to the accommodation. The existing layout would need to be adapted to suit the needs of any future specific occupier. In addition, the building fabric would need to be upgraded to meet modern requirements for energy efficiency. Building services systems would need wholesale replacement to suit the occupiers' needs.

4. Existing Site & Buildings Analysis

The Museum of London spaces are characterised by tall gallery spaces with ancillary spaces housed within mezzanine space, effectively creating two floors in the same volume as the main gallery spaces. These ancillary spaces are compromised in height which would likely be constrained for future occupiers. For the reasons (among others) the Museum of London is keen to move away from the site. It is therefore evident that there are significant limitations of the existing accommodation for reuse in its current configuration. It is likely that the Museum of London space would be let as a building shell for an incoming occupier to modify and fit out to suit their specific needs.

4.3.2 Assessment of reuse for alternative functions

Given the constraints of the existing spaces in the buildings the team have considered other potential uses for the existing buildings.

Bastion House
For Bastion House, the challenges around disproportionate collapse at the transfer level realistically preclude any significant change of use without significant technical and viability challenges. Putting those issues to one side, the structural grid constraints and limited floor-to-ceiling heights are the key limitations on delivering high-quality office space in the building. We have therefore considered its potential use as a hotel use or for residential use, as those functions typically have a lower ceiling height, and do not have the same demands for wider column grids, and therefore have some alignment with the spaces available.

A hotel would require the more significant interventions to the existing building. Additional vertical circulation (lifts) would be required as the existing lift cars are small and there is no goods lift. The addition of larger lifts, and indeed more lifts, would require significant structural works. Creating a hotel would also require additional vertical riser space for the distribution of water services, drainage and ventilation throughout the building requiring further structural interventions. The challenges around disproportionate collapse, mean that the structural interventions required to deliver these modifications are technically extremely challenging and not considered viable.

Residential use may require less structural intervention as the demands for vertical circulation and mechanical and electrical servicing are not as onerous. The existing lift shafts and potentially existing risers could be reused as routes for distribution of services. A change of use would still necessitate full recladding of the facade, additional upgrading of fire protection and fire integrity of the building structure. However, as this report sets out in the engineering commentary the inherent challenge of Bastion House around the potential for disproportionate collapse and carbonation makes a long-term reuse strategy for high quality residential accommodation and use also unfeasible and unviable in our view, and this is not something we are able to endorse.

Museum of London
The Museum of London building was designed for the specific requirements of a cultural institution in the 1970s/80s., which is now relocating to new accommodation (specifically because of the existing building and its site constraints). The double-height gallery spaces and constrained ancillary spaces do not easily lend themselves to alternative uses without significant modification of the structure and facades. Therefore, the use for alternative functions necessitates a more intensive adaptation of the building that will be considered later in this report.

4.4 Summary of Existing Buildings and Conclusions on Reuse

Engineering Challenges
The issue of disproportionate collapse, particularly in relation to the Bastion House Tower is significant. The technical and engineering viability of providing a replacement transfer structure is not considered appropriate from a structural, engineering, architectural or financial position. This significantly limits the potential medium-long term reuse of the Bastion House. The issue precludes change-of-use to a hotel with its requirement for additional opening for risers and vertical circulation. It also precludes change of use to residential as the potential risk of disproportionate collapse cannot be addressed whilst fully satisfying all design and engineering criteria and which would be raised through the building control process. The issues highlighted in terms of additional fire protection and carbonation would need to be assessed through detailed survey work, inspections and testing before considering appropriate mitigation measures, but both these matters also count against long term retention of the buildings.

Short-term solution versus long term vision
While a light office refurbishment for Bastion House could be completed, it would not address the inherent structural conditions of the building, and it would not address some of the current challenges of the space in terms of the spatial arrangement, energy performance, vertical circulation and riser provision. These would all require more significant alternations and interventions to address.

The space of the Museum of London, designed to the specific needs of the current occupier, is also highly constrained and has limited scope for adaptation to other uses given its bespoke 1970s/80s design for a museum space. A more minor intervention to re-use the Museum would be a short-term solution, but this does not meet the long-term ambitions of the site.

Commercial Considerations
As a public body the City of London is required to obtain best consideration and seek to maximise the value of its assets. Given all of the constraints identified, even if these could be overcome, retaining the existing structure would provide limited opportunity for extension and therefore limited opportunity to add gross area to finance the works and provide a return for the developer. A return for the developer, depends on several factors including, complexity, the size of the development, the perceived risks involved, the degree of competition between funding and finance institutions for the scheme, challenges of securing buildings insurance, the state of the market in terms of demand for and lot size of the completed development and the anticipated timescales for development and for receiving a return. It should be noted that the more risk involved, the higher return the developer will require. Therefore, given the risks associated with the matters outline above and limited gross area uplift, it would be unlikely that a developer would attempt to deliver the reuse schemes, as the risks involved combined with the limited financial returns available make them an unattractive investment.

Conclusion
Having looked at the feasibility of reusing the existing buildings we have concluded from the analysis above that a refurbishment option is not technically feasible, sustainable or viable. The next section of the report examines scenarios which provide a long-term solution for the site that address the inherent problems of the existing buildings, based on more extensive intervention including partial and full demolition.

5. Part demolition and full demolition options

Having regard to the above conclusions that there is considered no viable scheme based solely on retention and re-use, the design team have, in consultation with City of London officers in the Environment Department and Building Control Officers, considered and assessed potential part retention and redevelopment options for the site. This process looked at several ways in which the site could be redeveloped, taking relevant planning policy into account. The team examined how the inherent challenges of the buildings and site could be addressed and how wider benefits could be unlocked through site wide redevelopment.

We have looked at the impacts of delivering two alternative proposals of the site: The first option takes a critical look at maximising the reuse of the existing structures to conserve embodied carbon, balanced with strategic demolition and additions to the site that delivers a long-term solution through an uplift of high-quality commercial office space and cultural uses, that gets as close as is feasible to meeting the requirements of the brief. This option is referred to as Option 1 (Retain and Extend).

The second option is based on a wholesale redevelopment of the site. This assumes that the existing buildings are demolished, and new buildings are erected. Again, this looks to deliver a long-term solution to the site maximising the opportunity presented by this previously developed site to bring forward a commercial led scheme. This option is referred to as Option 2 (Redevelopment).

There are several intrinsic differences between the approaches and what they can deliver, summarized below:

Option 1 (Retain and Extend) has a more constrained development potential as it is limited by the structure of retained elements and therefore delivers a lower quantum of commercial and cultural space than Option 2 (Redevelopment). Option 1 also presents less opportunity to address the issues of how the buildings on site interface with the public realm. A driver for the development of Option 2 is that it allows the re-routing of the highway around the site, which unlocks an increased amount of public realm at both street level and highwalk level, providing enhanced permeability across the site. However, Option 2 involves more demolition, excavation and construction than Option 1, so the overall benefits generated need to be weighed against the additional construction waste and embodied carbon generated by this approach.

5.1 Option 1 (Retain and Extend)

This section describes in more detail the scenario of Option 1 which preserves some embodied carbon through retention of elements of the existing buildings.

The key features of the option are:

- Bastion House is demolished to podium level due to the inherent engineering safety challenges as previously outlined in this report
- Elements of the Museum of London are demolished to create better floor plates for new uses with better access to daylight and more usable configurations as illustrated on the following pages.
- Sub-structure to the existing buildings is largely retained and reused
- Retained structures are upgraded to meet modern standards for fire and integrity
- Façade elements are upgraded, - primarily new façade with some retained façade elements renovated to improve energy performance
- At podium level, additional low-rise structures are added to the Museum of London building to increase the deliverable floor areas
- A new building is constructed in place of the existing Bastion House tower with fewer storeys but improved floor-to-ceiling heights to reflect modern requirements in the same overall development height.
- A new building is constructed on the Rotunda to increase the development potential on the site
- The existing road network is left unchanged with minor improvements made to the pavement areas adjacent to the site.
- There is limited scope for new public realm and landscaping due to the level differences between street level and the existing buildings

Option 1 delivers a mixture of high-quality office accommodation in the Rotunda Building and New Bastion House with lower standard office accommodation within the retained structures, constrained by the existing building form. Cultural uses are accommodated primarily within the retained elements of the Museum of London building. Food and Beverage focused retail space is incorporated at street and highwalk levels.

It should also be noted that the retention of the existing structures limits enhancements to the public realm. The road configuration is left unchanged from the current condition in Option 1. Limited improvements to the street scape are possible because of the constraints of the existing roads. Furthermore, the limited existing public realm space on the site is lost to make way for the proposed Rotunda Building. The existing drive-through service road, accessed via a ramp from London Wall, would need to be maintained to service the buildings. This both limits the improvements to access the Barber Surgeon's Hall Garden to the east of the site and limits the possibilities of improving street level activation.

As Option 1 has some complexity in terms of extent of retention and extent of demolition over the following pages we have provided the illustrations to better describe the proposals in a series of steps:

5. Part demolition and full demolition options

5.1.2 Step 1 - Elements to be demolished and elements to be retained

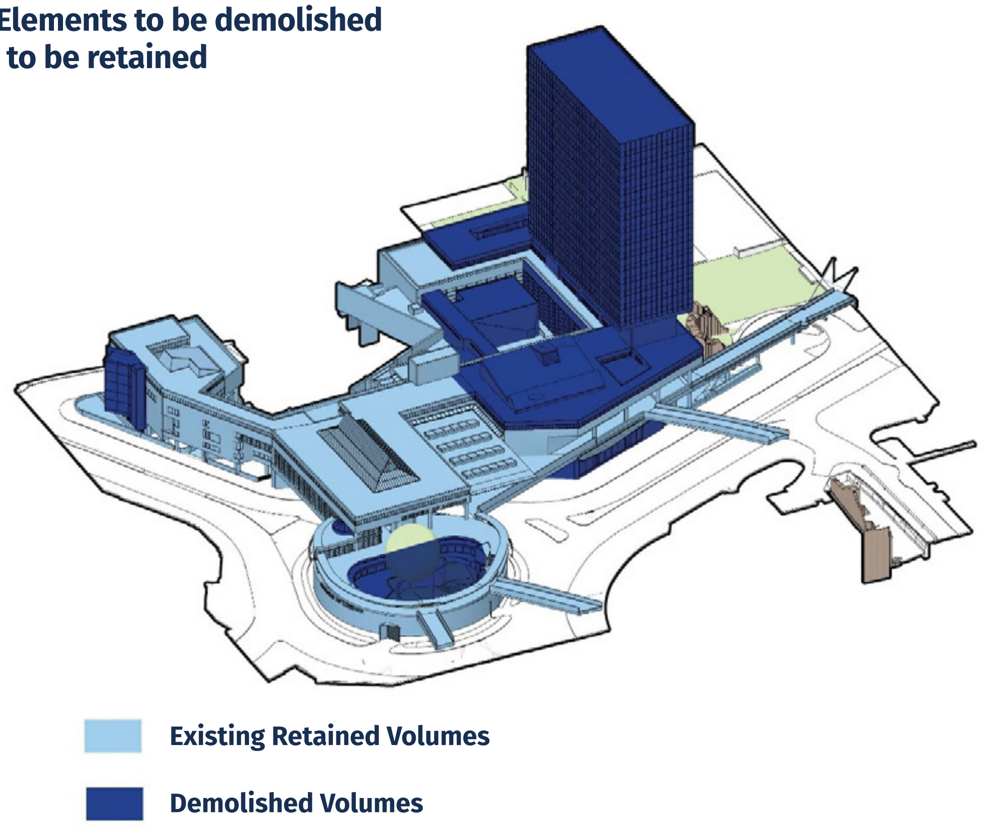


Figure 5—1 Elements of Demolition and Retention

- **Existing substructure, foundations and basements are retained**
- **Majority of Museum of London superstructure is retained**
- **Existing Road network maintained**
- **Demolition of existing Bastion House above podium level**
- **Demolition of other areas as indicated to improve redeveloped scheme**

5.1.2 Step 2 – Upgraded Elements

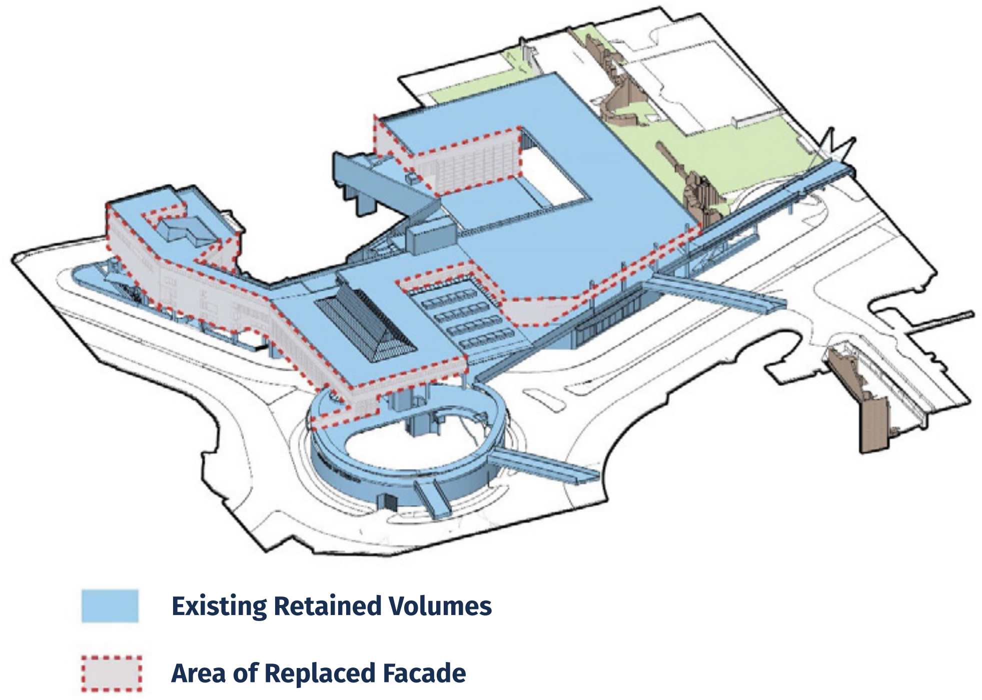


Figure 5—2 Step 2 – Elements to be upgraded

- **Fire protection of retained structure upgraded**
- **Extensive new and renovated façade cladding**
- **New MEP services throughout the development**
- **New lifts throughout the development**

5. Part demolition and full demolition options

5.1.3 Step 3 – Additional Low-Rise Structure

Figure 5—3 Step 3 – Additional Low-Rise Structures

- Modified entrance to London Wall to activate ground floor and accommodate level change
- Additional 1 & 2 storey lightweight extension to Museum of London building
- Additional massing to north of site on Aldersgate Street

5.1.4 Step 4 – New Bastion House

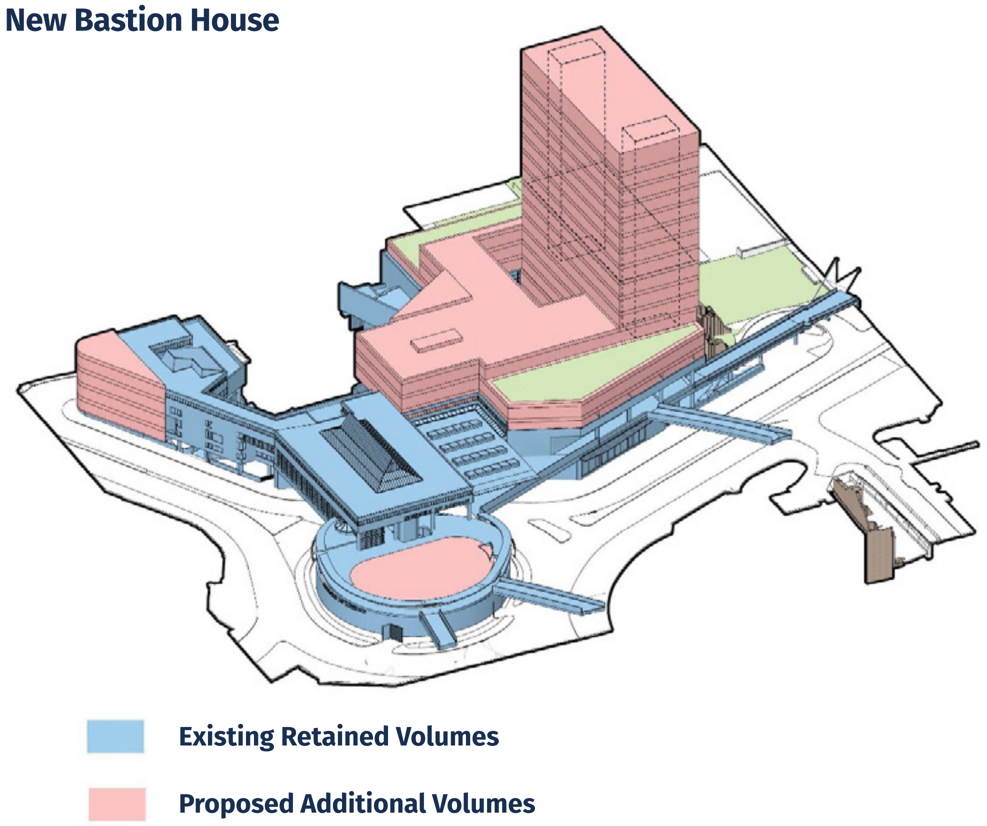


Figure 5—4 Step 4 – New Bastion House

- New Bastion House uses the footprint and foundations of the existing with modern floor-to-floor heights, lifts and services
- The height of the new building aligns with the height of the existing Bastion House building

5. Part demolition and full demolition options

5.1.5 Step 5 – New Rotunda Building

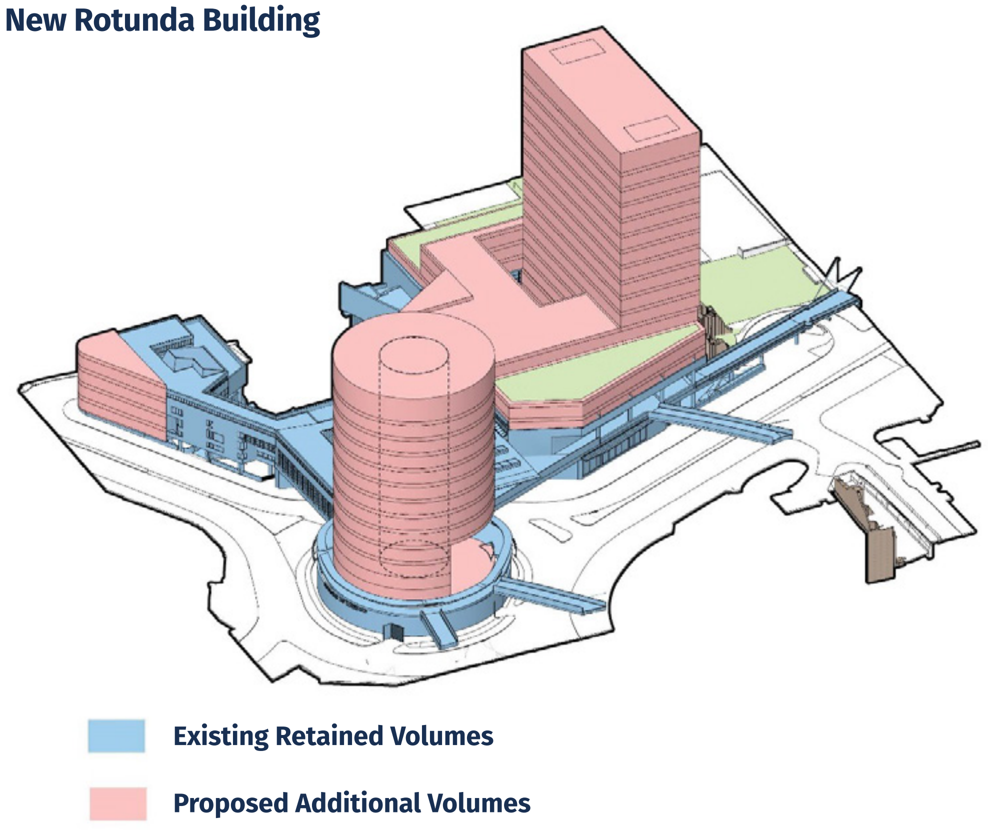


Figure 5—5 Step 5 – New Rotunda Building

- **New Rotunda Building uses the footprint of the existing Rotunda**
- **New substructure and foundations to support larger building than existing**
- **The height of the building is limited by reference to LVMF River Prospect views and local townscape views**

5.2 Option 2 (Redevelopment)

Option 2 would involve the demolition of the existing buildings, the construction of two large buildings and a third smaller one. The scheme would create 50% more office NIA, and 25% more non-commercial space compared to Option 1. In addition, improvements to the public highway system and public realm would be significantly greater. The new public realm extends between the two primary buildings at street level and highwalk level with improved permeability into the site and re-establishing the connection through to the Barbican Estate. This is an illustrative scheme based on early design proposals which are continuing to evolve.

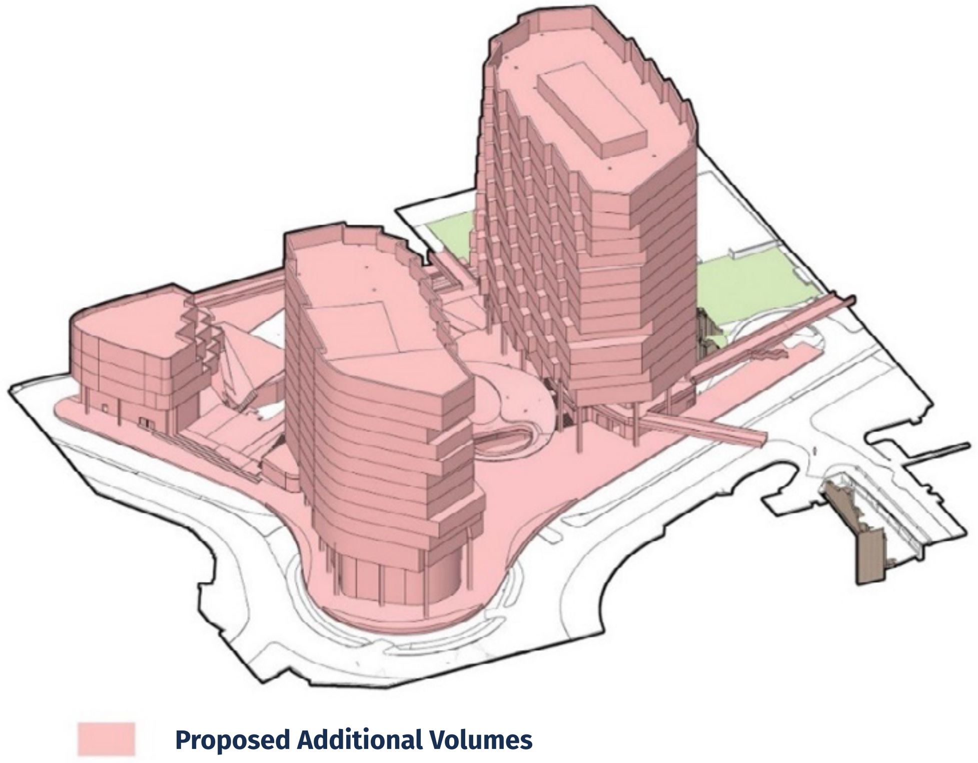


Figure 5—6 Option 2 (Redevelopment)

- **The demolition of the existing buildings on the site, and excavation to a new basement level**
- **The roadway would be re-routed to the south of the site and three commercial office-led buildings would be constructed and opening the opportunity for new potential public realm**
- **The development incorporates significant cultural, community and food and beverage focussed retail uses**
- **The office GIA from this scheme is approximately 50% greater than for Option 1 whilst the cultural and retail uses are approximately 25% greater**
- **Redevelopment allows for a larger more efficient scheme within the same height and massing constraints as Option 1 as the new buildings are not constrained by the existing road configuration or substructure**
- **Redevelopment allows the flexibility to deliver buildings of a higher architectural quality**
- **Significant public realm improvements are unlocked due to greater flexibility over where to locate the buildings**
- **The public realm can provide a large amount of new and improved publicly accessible landscaping and a more active streetscape**
- **An improved highway network at grade, with more intuitive navigation and enhanced permeability to the locality**

6. Whole Life Cycle Carbon Emissions

Having established two principal options for consideration a robust Whole Lifecycle Carbon Emission assessment can be completed to review the relative performance of each proposal. The following section of this report will look at the Whole Lifecycle Carbon Emissions of Option 1 and Option 2.

6.1 Whole Life Cycle Carbon Emissions Comparison

The purpose of the Whole Lifecycle Carbon Assessment is to look at the impact of the development in terms of carbon emissions. The Whole Lifecycle Assessment approach considers the carbon impacts from demolition of, and preparation of the site, through extraction of materials and construction and on through the operational life of the building to its eventual decommissioning and deconstruction. Carbon emissions are used as a measure of the climate impact of a development scheme. Carbon emissions for each stage can be calculated based on agreed methodologies and assumptions. The calculations are sensitive to the assumptions made and the methodologies used. In this study we have used the standard methodologies used by the GLA London Plan for the assessment. We have sought to be consistent with our assumptions in the cases put forward for comparison and we have presented the key assumptions in Appendix A, B,C and D of this report.

The two options we have considered in the following quantitative assessment are as described in Section 5 of this report. The two options are based on a number of assumptions subject to the broader consultation through the planning process.

Key factors that are significant to the outputs form this study include:

Design Resolution – The nature of a comparative study such as this is that we require sufficient detail to complete some meaningful modelling, but we do not have two fully resolved schemes for detailed comparison. Both options have been developed to an outline feasibility level of detail. The design team have developed sufficient detail to allow a reasonable comparison to be made but the information used for the basis of this study is not as detailed as would be provided for a planning application for each scheme. However, as the scheme develops it is likely that changes would be made to the form, massing, internal arrangements and facades of the development.To complete the whole lifecycle carbon studies, we have used precedent information from previous projects and to ensure comparability we have sought to use the same assumptions for each option except where there is a clear reason to differentiate. It is important to note that because of the stage the scheme is at when this assessment is completed, the two options under consideration are not fully resolved schemes from an architectural or engineering perspective.

Floor Areas – Option 1 is constrained by the existing site conditions, the existing layout and configuration of the route of the roadway, below ground layout and foundation design, the retained elements themselves, structural loadings and capacity. This means that Option 1 cannot deliver the same floor area as Option 2. As carbon emissions calculations are inevitably linked to the delivered floor area, this means that in absolute terms, carbon emissions will be lower from Option 1 which delivers reduced floor area compared to Option 2. We will therefore present carbon emissions in both absolute terms and in per m2 rates for comparison.

Building Uses – The design team have completed an architectural study of the development under Option 1 and Option 2. We have sought to allocate areas of the development to the same range and approximate proportion of building uses for each option. We have considered the opportunities, particularly within the retained structures of the Museum of London for their reuse as cultural and non-commercial office spaces on a best-fit basis. Through this process the proportion of area to office and non-office space has ended up slightly different in each scheme. This has a marginal impact on the whole lifecycle carbon emissions for each option. We could have corrected for this mathematically but, we felt it was more important to put forward realistic options rather than more abstract mathematical models for each scenario.

6.2 Methodology

The following section of the report goes through in further detail the comparison study undertaken.

The GLA defines the Whole Life-Cycle Carbon (WLC) emissions as “the carbon emissions resulting from the materials, construction and the use of a building over its entire life, including its demolition and disposal”. For the assessment presented here we are following the GLA London Plan methodology for assessing the whole life cycle carbon of the development. The approach set out in the guidance to the GLA London Plan requires the development to follow BS EN 15978:2011 (Sustainability of construction works – Assessment of environmental performance of buildings – Calculation Method) underpinned by the RICS Professional Statement (RICS PS): Whole Life Carbon assessment for the built environment which provides a practical guide to the implementation of BS EN 15978.

BS EN 15978 and RICS PS set out four stages in the life of a typical projects as a series of modules as follows:

- Module A1-A5 - Product Sourcing and Construction Stage
- Module B1 – B7 – Use Stage
- Module C1-C4 - End of Life Stage
- Module D -Benefits and loads beyond the system boundary

The carbon emissions within each module can be broadly divided from a calculation perspective into Embodied Carbon and Operational Carbon.

Embodied Carbon – The carbon cost of delivering the development from extraction of raw materials through to completion of the project on site, replacement through the life of the building and deconstruction at the end of the building’s life.

Operational Carbon – The carbon cost of operating the development over the lifecycle of the building.

Figure 6—16—2 Embodied Carbon and Operational Carbon

6. Whole Life Cycle Carbon Emissions

The Embodied Carbon and Operational Carbon have been assessed for Option 1 and Option 2 as set out in this section. The Whole Lifecycle Carbon Emissions of a development are made up of the Embodied Carbon and Operational Carbon over an anticipated building lifecycle.

The assessment presented here is carried out over a nominal 60-year building lifecycle as per the standard GLA methodology. By incorporating Circular Economy principles into the design of a new build scheme we would envisage a significantly longer lifespan for Option 2. Elements of Option 1 may also achieve a greater than 60-year lifespan but for elements reliant on reuse of the existing structure this would be potentially less achievable because the retained structure is already approximately 50 years old.

6.3 Embodied Carbon Assessment

Embodied Carbon has been assessed using the One Click LCA methodology®. This methodology is a standardised, science-based tool for quantifying the impact in order to assess lifetime environmental impact. LCA takes into consideration all the steps that lead from raw material through manufacture, distribution, usage to final disposal. The methodology is based on international standards, ISO 14040 and 14044. The One Click LCA methodology is the approach used to provide input to independent sustainability assessments such as BREEAM and LEED.

The assessment of building material quantities and types have been estimated by the specialist designers based on the information produced to date for each option. The carbon intensity of each material is taken from standard reference data for each material or manufacturer's certified declarations for their products.

Appendix B of this report provides the outputs from the One Click LCA assessment.

6.3.1 Inputs to the Embodied Carbon Assessment

To complete the preliminary Embodied Carbon assessment the design team have developed massing models and areas of the two options under consideration. These schemes have been developed to provide information to the carbon assessment and should be considered illustrative rather than fully resolved proposals. The preliminary schemes have been used to assess the floor areas, space usage, façade areas and the conceptual feasibility of each option. This approach has also enabled the team to identify which elements of the existing building are suitable for retention and adaptation.

The estimated material quantities for each option (and therefore the associated embodied carbon) have been developed using a series of studies and benchmarks. For example, the estimated waste from excavation and demolition for each option has been assessed by a waste specialist, their assessment is included in Appendix D of this report.

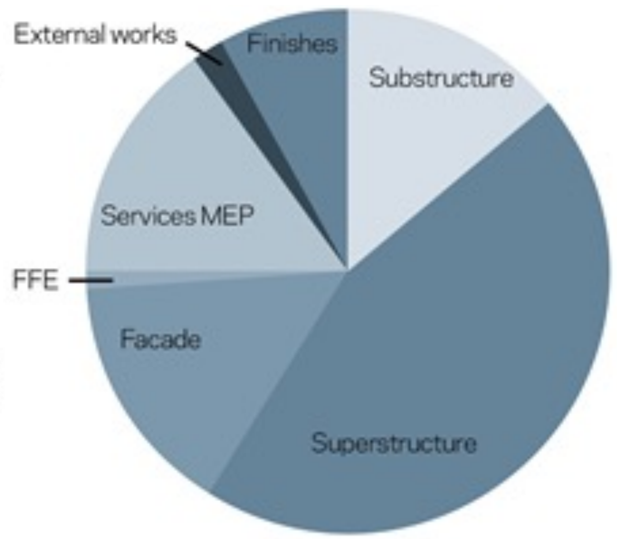


Figure 6—3 Typical breakdown of Embodied Carbon by Element of new build office development

The chart below represents the typical breakdown of Embodied Carbon within a commercial building. Typically, more than 50% of a new build development's embodied carbon is in the substructure (foundations etc.) and the superstructure (framing, floors and cores). The façade and the installed building services then make up the next most significant proportions of embodied carbon.

For this study, the embodied carbon of the superstructure has been assessed by looking in detail at a structural bay study for a new build part of the development. Through the early design stages, the bay study is used to assess a range of different potential construction approaches and calculate their embodied carbon. A number of different material solutions have been considered for the structure including timber, concrete frame and hybrid structural solutions. The analysis of the different material options considered will be provided in the planning stage Whole Life Cycle Carbon assessment for the submitted scheme. For this comparative assessment of the two development options under consideration, the superstructure is based on a highly efficient steel and concrete solution which delivers a good balance of embodied carbon performance and other factors including fire safety, cost, adaptability and flexibility for example. The structural solution developed in the bay study informs the predicted carbon emissions for the substructure too. A heavier superstructure requires heavier substructure. The substructure solution in this study is consistent with the superstructure system described above. The embodied carbon assumptions are consistent for new superstructure for both Option 1 and Option 2.

The carbon emissions associated with the façade have also been assessed for both options. To do this efficiently, we have used benchmark data from previous projects using a similar façade typology as would be utilised for the buildings in Option 1 and Option 2. At this stage, this is based on a high-performance aluminium framed, double glazed unitised façade system. As this is based on precedent data, we have accurate and realistic material quantities for systems that can then be used to estimate the embodied carbon of the façade on a per m^2 basis. Following the same principle as described above for this comparative study, we have used consistent assumptions for Option 1 and Option 2.

The building services systems for a building are the active elements that provide heating, cooling ventilation, lighting, drainage etc. Although there is a growing appetite to understand the embodied carbon impacts of these systems, there is currently limited data available on typical building services installations. To adequately assess the impact of building services systems we have used the best available 'typical' benchmarks and again to be consistent between the two options under consideration. We think that this is a reasonable approach for this comparative study. To accurately assesses the embodied carbon of the building services systems would require a detailed design to be completed for both options under consideration and so is not possible at this stage of the development process. The benchmarks used for building services systems in this study are from LETI - the London Energy Transformation Initiative.

6. Whole Life Cycle Carbon Emissions

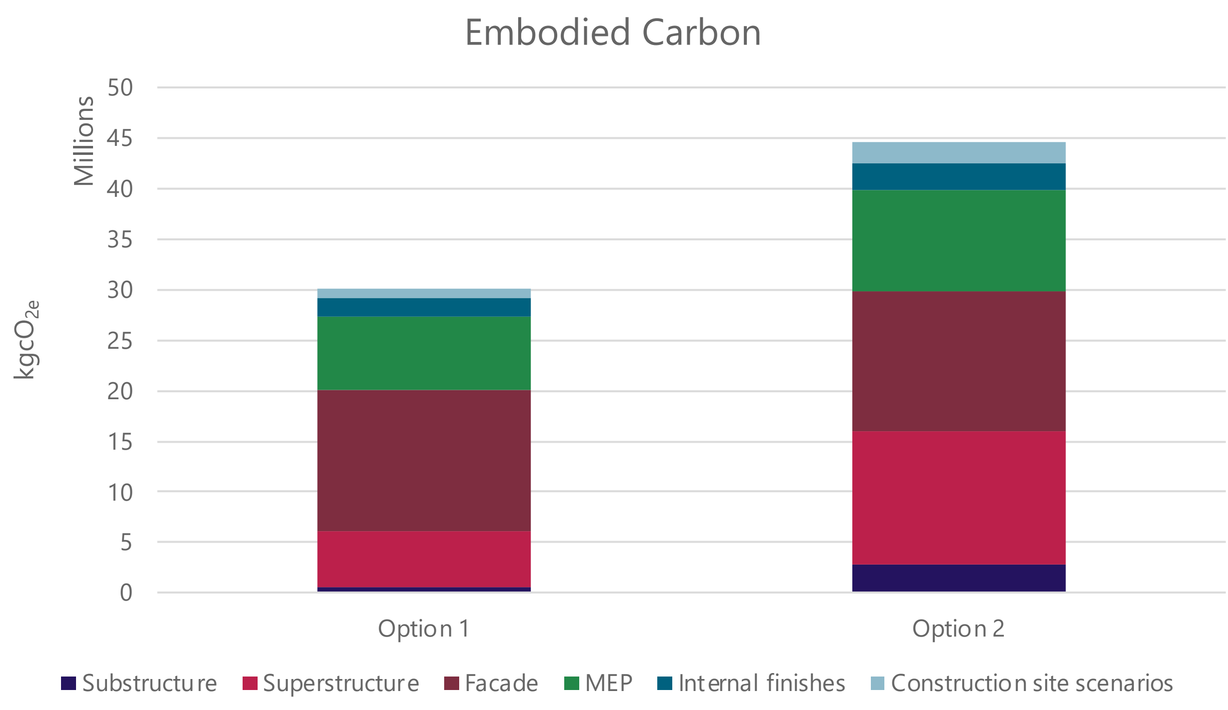


Figure 6—4 Comparison of Embodied Carbon

The LETI guidance also provides benchmarks for the internal finishes for each option which have been used consistently between the two options.

The results from the Embodied Carbon Assessment in absolute terms are presented in.

This chart shows the estimated Embodied Carbon in Millions of kilograms of CO_2e for Option 1 and Option 2. In absolute terms, Option 2 generates approximately 15 million additional kilograms of carbon dioxide equivalent compared to Option 1. This is approximately a 50% uplift in Embodied Carbon.

This differential is not unexpected and is driven by two key factors. Firstly, Option 2 is a bigger scheme delivering more building area than Option 1. It delivers approximately 40% more Gross Internal Area (GIA) in comparison to Option 1, but also requires more material in its construction. Secondly, Option 1 conserves Embodied Carbon through the part retention of substructure and superstructure. Option 1 does however require a significant investment of Embodied Carbon for the substructure to the new Rotunda building, the modifications and extensions to the Museum of London building, the superstructure to the new Bastion House building as well as the new façade and building services installations.

Despite Option 1 being smaller in terms of GIA, the Embodied Carbon associated with the façade is approximately the same for both options. It is a fundamental assumption of the study that to achieve the long-term energy performance of the scheme a new facade will be required in both options. Option 2, with the flexibility of a new development, can deliver a more efficient building form. This means that the overall area of façade is actually reasonably similar for both schemes despite Option 2 delivering a significant uplift in floor area.

The absolute carbon emissions outlined above are useful to understand but the embodied carbon per m^2 isalso relevant for a comparative study. The comparative results for embodied carbon per sq m are shown in below.

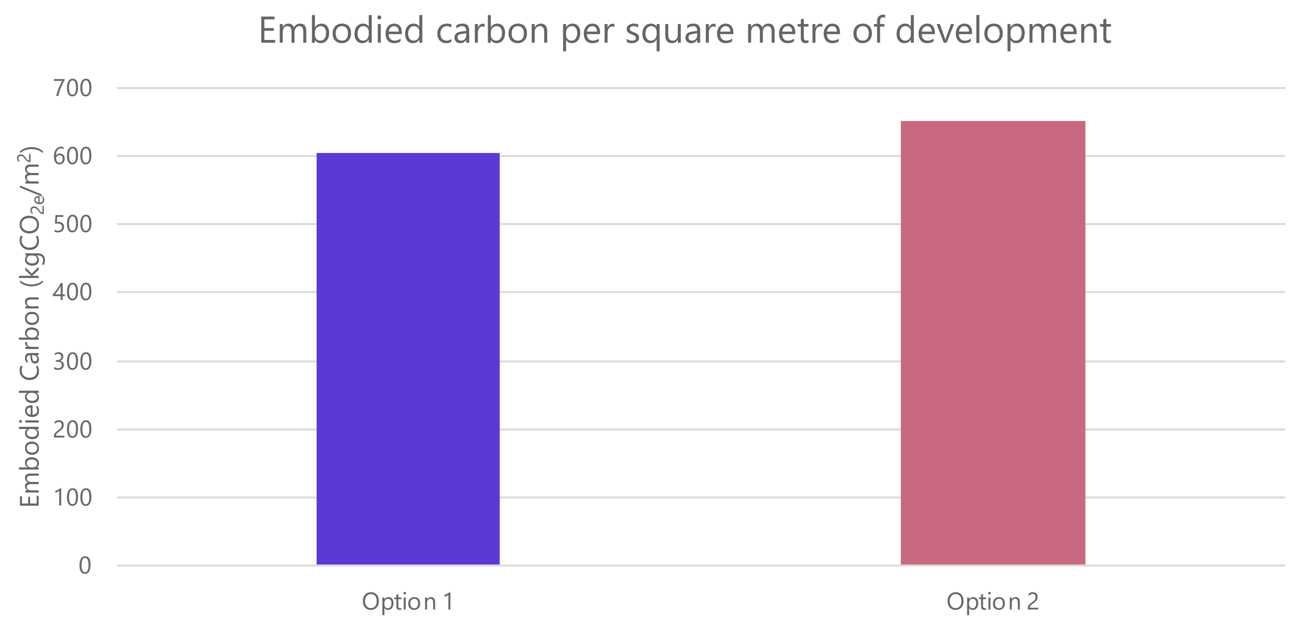


Figure 6—5 Embodied Carbon per Square Metre of Development

The carbon emissions per m^2 for Option 2 are just 8% higher than for Option 1. This shows that both scheme options require a significant investment of embodied carbon. The embodied carbon savings benefit of Option 1 of the structure and sub-structure is limited when considering the planning policy objective to maximise the potential of the site. The retention of the existing structure and substructure limits the efficiency of the development site in terms of spatial planning and potential to optimise the form of the buildings.

6.4 Operational Carbon Assessment

The Operational Carbon Assessment has been completed following the methodology set out in CIBSE Technical Memorandum 54 (TM54) Evaluating operational energy use at the design stage. This methodology uses dynamic thermal models which reflect the geometry, services installations and usage patterns. Usage patterns and active systems have been modelled based on inputs from the specialist designers. The building fabric performance has been assessed based on input from the architectural and façade designers. The results are calculated initially for one year.

The principal assumptions that form the basis of the Operational Carbon Assessment are presented in Appendix C of this report. The assumptions made are consistent for Option 1 and Option 2. It could be argued that the lower financial return for Option 1 would result a lower investment in energy efficient plant and equipment. We have not taken this approach but have assumed that the installed systems would be equivalent for each option. We have also assumed that both options would provide photovoltaic panels as an on-site renewable energy source. We looked at the

6. Whole Life Cycle Carbon Emissions

suitable exploitable area for each option and concluded that it would be achievable to deliver a larger area of PV relative to the delivered GIA footprint for Option 1 compared to Option 2. This provides a slight 'advantage' to option 1 in energy terms.

One of the key assumptions of the Operational Carbon assessment is the future carbon intensity of the primary energy source. At present the development site is connected to the Citigen District Energy network for both heating and cooling. The Citigen network is going through a process of decarbonisation but as yet, future predicted carbon intensities are not available for use in studies such as this. A separate Energy Strategy study is underway for the development which will consider the benefits and challenges of connecting the developed site to the Citigen Network and will be submitted with the planning proposal. As this is a comparative study of two options, as long as the assumptions are consistent, the relative assessment is valid. We have therefore assumed that both Option 1 and Option 2 will use electrically driven heat-pump systems for both heating and cooling. This is current best practice for energy strategies for schemes of this scale. This approach drives carbon savings by taking advantage of the decarbonisation of the UK's electricity supply network and a move away from fossil fuels. Making this assumption for the Operational Carbon assessment does not preclude using a connection to the Citigen network for the planning energy strategy or in the future subject to establishing the carbon impacts of this decision at the time.

Having completed the analysis for each option, below show the absolute carbon emissions in $KgCO_2$ per annum for Option 1 and for Option 2. This shows that the annual operational carbon emissions for Option 1 are lower than for Option 2. This is as would be anticipated as Option 1 delivers a smaller quantum of floor area.

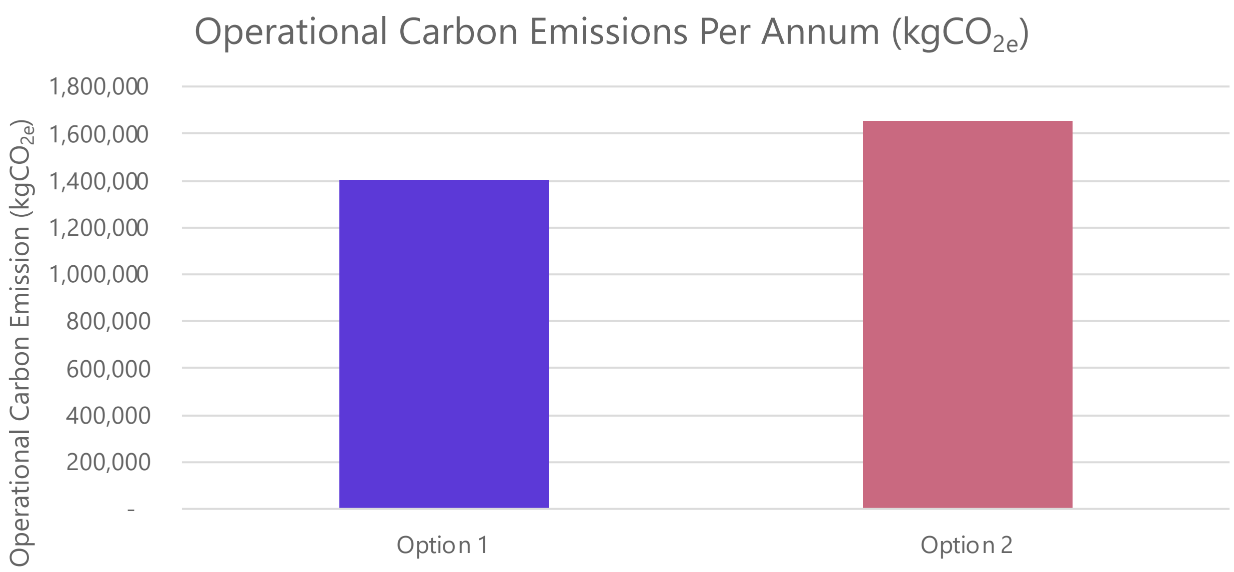


Figure 6—6 Operational Carbon Emission per Annum

Again, as per the Embodied Carbon study, the Operational Carbon study is highly dependent on the scale of the development and hence total floor area. We have therefore also looked at the breakdown of these carbon emissions per m².

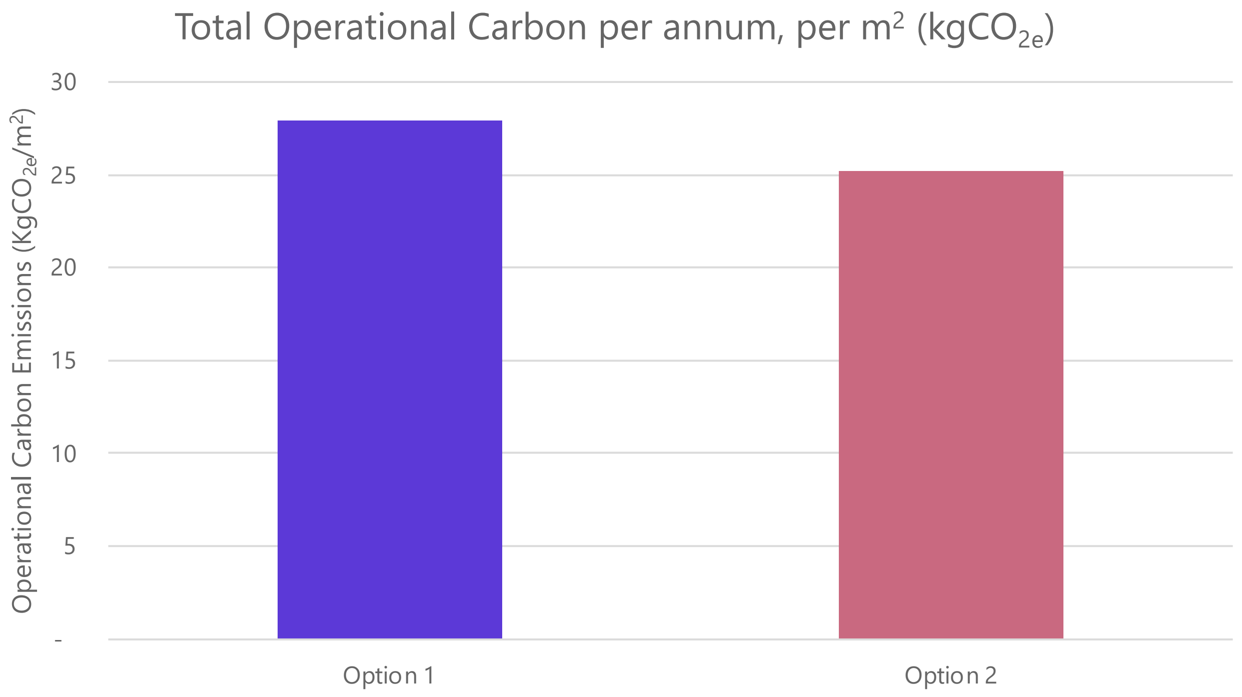


Figure 6—7 Operational Carbon per square metre, per annum

The results of the operational energy model show that Option 1 generates more operational carbon emissions per square metre compared with Option 2. The operational carbon emissions are approximately 17% higher on a per m² basis. From our analysis there are three key drivers for this difference:

Façade to floor ratio – Option 1 provides less spatially efficient office accommodation. One measure of this is that per sq.m of floor area, there is a higher area of façade. The façade area is very closely linked to energy demands for heating and cooling of buildings. A high façade to floor ratio therefore means higher energy demands, particularly for cooling.

Worse performing building envelope – It is not feasible to achieve the same levels of air-tightness and thermal performance from replacement facades as from new-build facades. We have assumed that the component performance of all new constructions for Option 1 will be equivalent for option 2 but that it will not achieve the same levels of air-tightness or thermal performance in the retained and refurbished elements. The retained envelope is upgraded to meet and exceed in some cases the standards required for current building regulations but does not achieve the same standards as a newly constructed envelope.

6. Whole Life Cycle Carbon Emissions

Proposed building uses – Both options deliver proportionately similar floor areas of non-office use (cultural uses, community uses and cafes etc). These spaces have higher energy demands in comparison to office uses and so therefore greater operational carbon emissions. Although we have provided uses as close to proportionate as possible, there is a higher overall proportion of non-office use areas. This means that on a per m² basis, Option 1 has marginally higher operational carbon emissions from the non-office elements. We considered adjusting for this using a mathematical model but, on balance it was felt right to compare schemes based on what we thought was deliverable within the constraints of the existing and proposed elements.

It is difficult to isolate the relative impacts of each of these three factors in the model because of the interrelation between the three.

6.5 Whole Lifecycle Carbon Assessment

The Whole Lifecycle Carbon assessment is completed by combining the outputs form the Embodied Carbon Assessment and the Operational Carbon Assessment. We use the One Click LCA ® tool to combine the two modelling outputs from the Embodied Carbon and Operational Carbon Assessments. The Whole Lifecycle Carbon Assessment is taken over an anticipated 60-year building life as per the GLA methodology, albeit a new build option would be designed for a greater design life.

Again, we have looked at the results initially in absolute terms and then on a per m² basis.

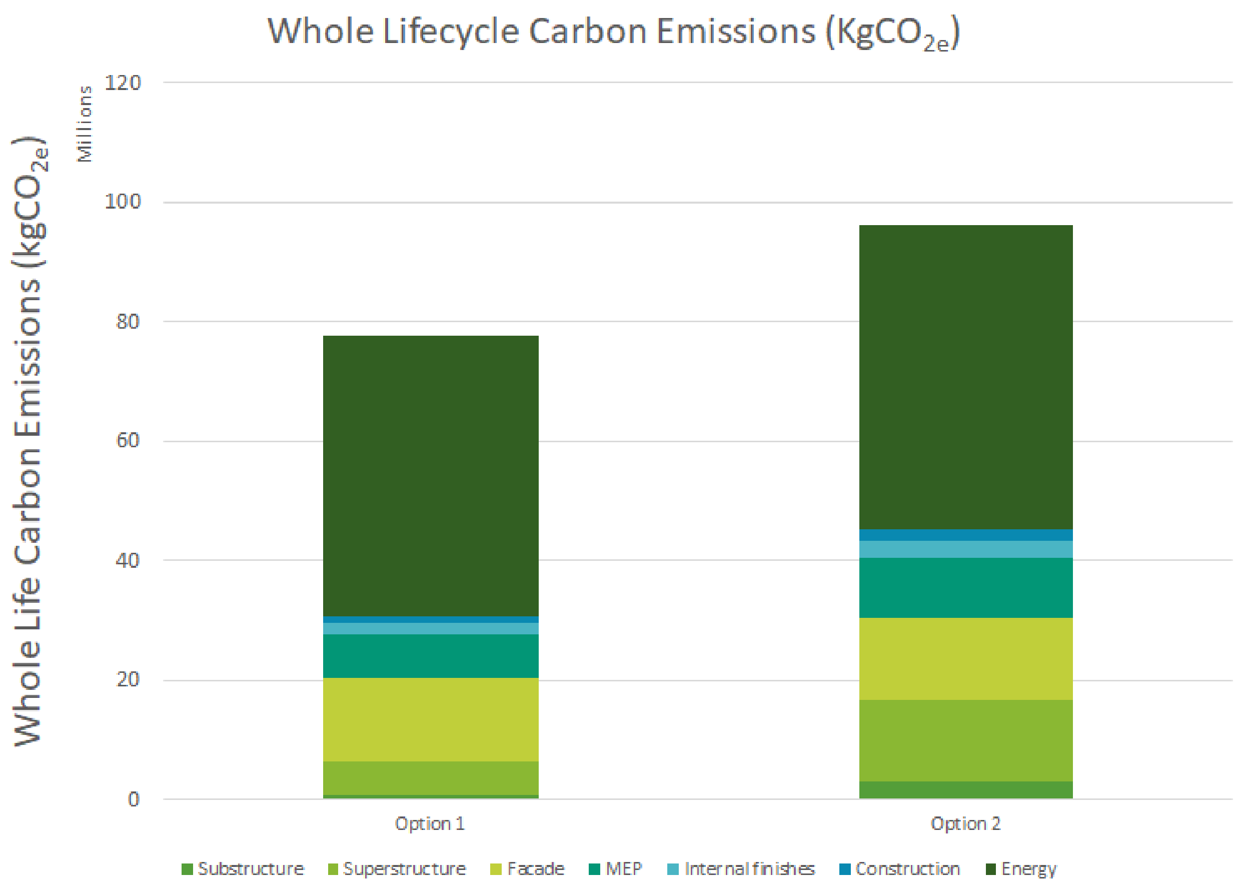


Figure 6—8 Whole Lifecycle Carbon Emissions in millions of kilograms of CO_2 equivalent

The absolute Whole Lifecycle Carbon results are again presented in millions of $kgCO_2e$ and show that in terms of absolute carbon emissions Option 1 has lower Whole Lifecycle Carbon Emissions compared to Option 2. The absolute carbon emissions for Option 1 are approximately 20 million kilograms or just over 20% lower for Option 1 compared to Option 2. The higher absolute Whole Lifecycle Carbon Emissions for option 2 is directly related to increased floor area delivered by that scheme.

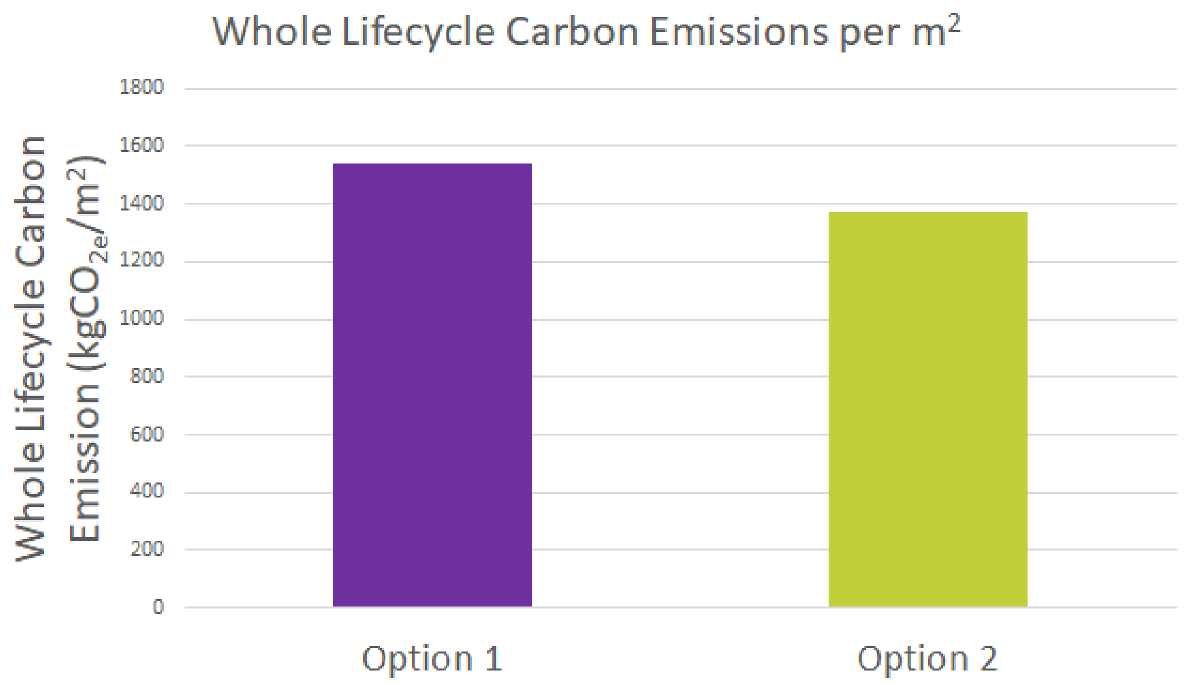


Figure 6—9 Whole Lifecycle Carbon Emissions per m²

However, when we consider the whole lifecycle carbon emissions on a per m² basis the analysis demonstrates that the Whole Lifecycle Carbon Emissions from Option 2 are approximately 10% lower on a per m² basis than for Option 1. This again reflects the efficiency that can be achieved in the redevelopment option and the increased floor area that can be delivered within similar constraints.

The increased floor area delivered in Option 2 means that in absolute terms, Whole Lifecycle Carbon Emissions will be higher but these additional carbon emissions have to be balanced against the benefits unlocked through the creation of the additional commercial floorspace in the Square Mile and CAZ and the numerous planning and public benefits arising for a full redevelopment scheme.

6.6 Conclusions on Whole Lifecycle Carbon Assessment

The Whole Lifecycle Carbon Analysis shows that both Option 1 and Option 2 require a significant investment of carbon in terms of Embodied Carbon and Operation Carbon to deliver and operate the developments The studies show that the increased floor area delivered by Option 2 means that absolute whole lifecycle carbon emissions will be higher for the larger scheme. The studies also show that the efficiencies achievable with Option 2 mean that on a per m² basis, whole lifecycle carbon emissions will be lower for Option 2 over 60 year, albeit we should expect the development to last longer than 60 years

This is principally due to the efficiencies unlocked through the wholesale redevelopment which removes a number of constraints of the existing structures.

7. Mitigation Measures and Public Benefits

7.1 Mitigation Measures

Having regard to the analysis in Section 6, it is also necessary to have regard to other planning policy objectives and material considerations in respect of re-development proposals. These would be fully set out in any future planning application, In this section we briefly highlight key considerations that will be need to balanced against the carbon analysis set out in this report, recognising that carbon emissions is only one, albeit important, planning consideration.

It is acknowledged that, as for any new build development, a significant investment of materials and carbon is required. To seek to mitigate these impacts, the proposed development will seek to be a leading example of sustainable new-build design. Key measures that will be targeted include:

Net Waste Positive Development
Through the demolition of the existing building and construction activities, this development will generate waste. A pre-development building audit is underway to assess the materials on site at present. This will identify materials and provide routes to reuse each element in its highest possible value state. The development team will work with waste specialists to find uses for materials arising from the deconstruction, demolition and excavation phases of the development. Through this process we will seek to divert 95% of demolition waste by weight from landfill. We are also looking to go beyond these commitments. We want to aim for the construction phase of the development to use waste from other demolition sites in the City of London. Primarily through the use of recycled concrete as an aggregate, we want to see if we can deliver a development that will be a net user of waste from the City of London.

Designing for a Circular Economy
The proposed new build scheme will be designed with a focus on the Circular Economy. The aim is to ensure that the building can adapt through its useful life and can be reclaimed and reused when no longer fit for purpose

As described in this report the existing buildings present constraints for their successful reuse. Our approach is to design new buildings to avoid these challenges for future generations. Our approach to Design for a Circular Economy will be set out in our planning submission. Key principals that we will follow include:

- Designing in layers – For example, designing the building shell for 50-75 years, the services for 15-20 years and the interiors for 10-15 years. By considering this at design stage we can ensure easy upgrade of the building thorough its life.
- Designing out waste – maximising efficiency of the building materials, prioritising off-site manufacture
- Designing for adaptability – whilst delivering a high-quality commercial building we will test the floor plan for different future uses; residential, hotel, education
- Designing for disassembly – we will consider the building as a bank of materials for future generations. We will separate technical materials and biological materials to maximise recyclability and compostability
- Consideration in our material selections – we will target recycled materials, we will match material to life-expectancy, we will prioritise 'biological' materials

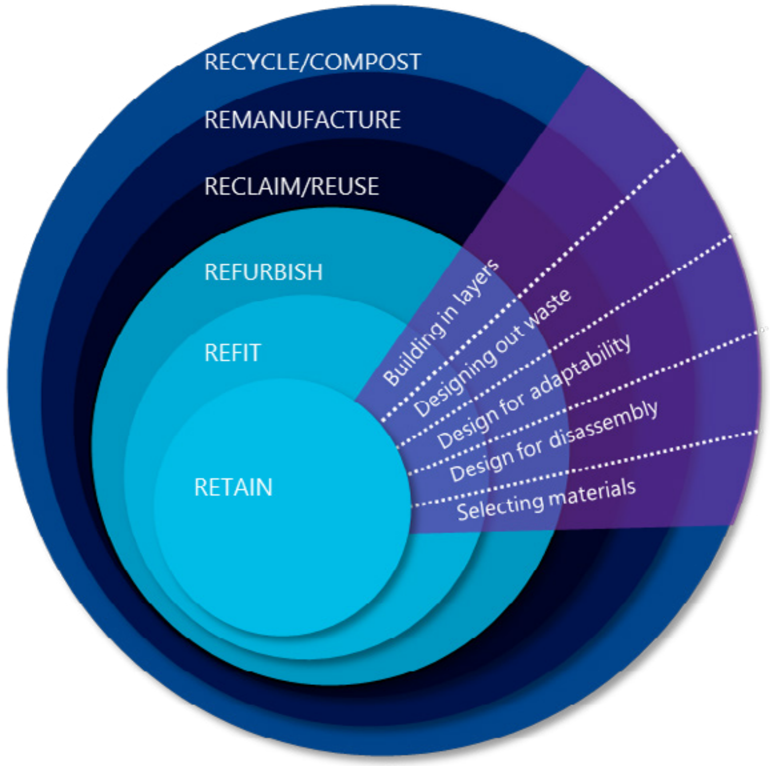


Figure 7—1 Circular Economy Principles - Source: Building Revolutions (2016), David Cheshire, RIBA Publishing. Reprinted in London Plan 2021 Figure 3.2

Net Zero Carbon Development
We are committed to ensuring that the London Wall West Development site will be a Net Zero Carbon Development, including through the offsetting of Embodied Carbon in the development. Our strategy for achieving this will be set out in future planning documentation.

7.2 Public Benefits

It is also necessary to evaluate the public and planning benefits the schemes can deliver. The key benefits driven by option 2 in comparison to option 1 are set out below:

Economic Benefits

- The redevelopment scheme can deliver approximately 40,000m^2 of new high quality, sustainable office workspace, (approximately an additional 15,000 m^2 over option 1), which optimises the development to meet a range of business needs across the Square Mile, enriching the City of London as a primary business centre of national and international importance.
- The greater overall scale of the commercial workspace that can be delivered by Option 2 can facilitate supporting approximately 500sqm of affordable workspace/maker space to support growing businesses with a focus on the arts and culture sector. This area would be proportionally smaller in option 1 due to reduced floor area of the development.

7. Mitigation Measures and Public Benefits

- While option 1 upgrades the quality of the office space beyond what exists on the site today, there are inherent constraints of the existing conditions that limit the footprints of the building resulting in inefficient floorplates for space-planning needs of modern businesses and therefore delivers a lower employment density relative to the scale of the development than can be achieved by option 2. Option 2 optimizes the efficiency and employment density achievable on the site.

- Whereas Option 1 diminishes what little existing public space there is, Option 2 provides a much-improved environment and public space which can enhance both the development site itself, but also bring more retail, food and beverage, and other associated economic activity to the area (See also social and environmental benefits).

Social Benefits

- Option 1 cannot significantly enhance the public realm experience of the site due to the configuration of the existing roads, the tunnel over the roundabout, and the configuration of the floor levels of the museum building which are not level with the existing street. In contrast, Option 2 offers the opportunity to make a highly accessible and permeable series of routes and spaces through and around the site, improving intuitive circulation, and enhancing connectivity to the Barbican Campus

- In its own right, the site can also continue its role as a cultural destination. Option 2 can create a much more welcoming interface of urban space & cultural space (4000 m2) which can activate the streetscape, act as a cultural landmark from select vantages (with the 'cultural cap' providing a roof-top space) and act as a catalyst for change in this part of the City linking in to the Culture Mile.

- Option 2 provides new community use space, suitable for a variety of functions as needed by local stakeholders.

- The existing road junction is a known accident hotspot for collisions between cyclists, pedestrians and vehicles. The revised road configuration in Option 2 provides a safer pedestrian and cyclist experience in and around the site with dedicated cycle lanes, signalized junction and pedestrian crossings. Moreover, the pedestrian experience moving through the area of the site can be greatly improved with the removal of the tunnel over the roundabout.

- There is a significant uplift in the amount of public space on the site in option 2 versus option 1 (including an uplift of 2000 m^2 hardscape (40% increase) , and 2400 sqm landscape (75% increase from the option 1). Conversely, Option 1 diminishes the quantity of green space from the existing conditions (losing the existing Rotunda Garden, and public space is restricted to linear walkways without any urban space for dwelling. In contrast Option 2 creates a series of new public open spaces including both hard and soft landscapes of varying characters and amenity: spaces scaled for individuals, small groups and gatherings, and spaces for quiet repose in the landscape or more active cultural use and events.

- Option 2 presents the opportunity to reveal Ironmongers' Hall which is currently entirely hidden from the street, and would remain so in Option 1. Further, there are new views through the site to the Barbican enhancing visual permeability and connectivity within the public realm.

- Regarding the heritage and archaeology assets of the site (the City Wall fragment being a scheduled ancient monument), there are several key differences in the possible responses of each option. Option 1 would require the retention of the current site service road, and thereby restrict the ability to enhance access to the Barber Surgeons' Garden, and parts of the Roman Wall in contains. Furthermore, the access to the Roman Gate would be rather more difficult to improve in a meaningful manner. Option 2 on the other hand would create improved visual and physical accessibility to the Garden and facilitate the provision of free public access to the currently concealed Roman Gate. New highwalks would also overlook the garden providing new vantages to appreciate and understand the early formations and history of the City. The setting of the fragments of the wall in the garden will be enhanced by plantings and the updated backdrop provided by the new architecture.

Environmental Benefits

- As has been described above, there is an increased area of public open space and green space. These can deliver fantastic public realm within the masterplan, and a range of landscape that can significantly increase biodiversity and ecology across the site: with the new central landscaped glade, the Woodland Garden, Ironmongers Plaza, but also building upon the qualities of existing ecologies.

- Option 2 can deliver significant urban greening and biodiversity measures on the ground level, podium level, and buildings themselves – with planting at terraces throughout the height of the buildings, and the upper roof levels.

- Deliver highly sustainable development targeting BREEAM "Outstanding" beyond the minimum planning requirements and, delivering significant carbon dioxide reductions through implementing new efficient all electric plant and renewable technologies (where possible) to improve energy efficiency and reduce greenhouse gas emissions.

- Funding alterations to the roadway to suit the requirement of the 21st Century and to create a better experience for pedestrians and cyclists

- Delivering a sustainable servicing strategy which includes off site consolidation

In summation it is considered that the benefits arising from option 2 are much more significant than those arising from option 1, and therefore weighed in favour. The proposed redevelopment scheme delivers a range of public benefits for the City of London, the Central Activities Zone and the stakeholders. and presents the opportunity to create a catalyst for change and wider regeneration of the Barbican and Smithfield area, as one of the seven key areas of change at the heart of the Culture Mile. As such, this option can best enable the site to serve as a mediator of the economic, cultural, and civic aspirations of the city.

8. Conclusions

This report has summarised the assessment and analysis by the design team of the existing buildings on the London Wall West site and their structural, architectural and safety considerations. It has been prepared to give stakeholders an understanding of the reasons why the design and client team are bringing forward a redevelopment for the site. A comprehensive assessment and analysis of the existing buildings and their structural, architectural and safety considerations have been carried out. The analysis has shown that the existing buildings are compromised and present a number of significant challenges in terms of their potential reuse. The appraisal of the existing buildings sets out a number of technical challenges that mean their retention in full is not a long terms solution for the site.

The report then considers two development options, both of which achieve new volumes of development to unlocking the potential of the site. The site is identified as an important part of the Square Mile in terms of achieving the Corporation's strategic objectives for sustainability, culture and commerce, driving post-pandemic recovery to create a 24 hour a day, 7 day a week City for workers, residents and visitors. Option 1, a part-retention, part demolition scheme provided an uplift in commercial office area, cultural space and food and beverage space. Option 2 a new-build development option provided further additional area and extensive enhancement to the public realm.

To assess the impact of both options from the perspective of carbon emissions, a comparative Whole Lifecycle Carbon assessment was completed. This took into account Embodied Carbon and Operational Carbon Emissions for each option over a 60-year design life.

The conclusion of this study was that on a per-square metre basis Option 2 performs 10% better than Option 1. As Option 2 is larger, in absolute terms, Option 2 has higher Whole Lifecycle Carbon emissions.

The carbon emissions need to be balanced against a range of factors including other planning policy objectives and the planning and public benefits arising. It is the view of the project team that option 2 achieves significantly more benefits for the reasons set out in this report.

It is acknowledged and understood that this means additional carbon investment is required in the buildings. It is also considered that retention of the existing building fabric would not, in this case, achieve the Corporation's aspirations to unlock comprehensive development at the site. Further, the redevelopment would be highly sustainable remain in place for at least 60 years, with the intention being that these buildings remain in place for significantly longer. The new buildings would be designed for flexibility, with circular economy principles at the heart of the design. It is for these reasons that option 1 has been discounted and option 2 is being taken forward as part of an application for full planning permission.

Accordingly, this report provides a justification for demolition of the existing buildings having regard to the WLC assessment. It is evident that the carbon analysis for the options needs to be balanced against the benefits of the redevelopment scheme. It is considered that full redevelopment represents the most sustainable development having regard to the analysis in respect of carbon and the wider benefits achievable in option 2 over and above those in option 1.

Appendix A. Whole Life Cycle Carbon Assessment – Key Assumptions

A.1 Area schedule

OPTION 1 - TOTAL										
				Measured NIA						Not NIA
GEA (approx. sqm)	GIA (approx. sqm)	NIA (approx. sqm)	Nett to Gross	Office		Retail F&B		Other		Service [not NIA]
Measured	Measured	Measured	% *NIA / GIA*	m2	% of NIA	m2	% of NIA	m2	% of NIA	
										-
129	97	-	0%							97
909	844	701	83%	701		-		-		143
909	844	701	83%	701		-		-		143
1,098	1,009	701	69%	701		-		-		308
2,104	1,978	1,646	83%	1,646		-		-		332
2,104	1,978	1,646	83%	1,646		-		-		332
2,104	1,978	1,646	83%	1,646		-		-		332
2,104	1,978	1,646	83%	1,646		-		-		332
2,104	1,978	1,646	83%	1,646		-		-		332
2,104	1,978	1,646	83%	1,646		-		-		332
2,104	1,978	1,646	83%	1,646		-		-		332
3,630	3,406	2,663	78%	2,663		-		-		744
3,563	3,345	2,625	78%	2,625		-		-		720
5,606	5,327	4,149	78%	4,149		-		-		1,178
2,282	1,871	702	38%	702		-		-		1,169
5,231	4,921	3,566	72%	2,122		1,444		-		1,355
3,114	2,725	1,456	53%	1,096		-		360		1,269
5,905	5,659	3,221	57%	-		-		3,221		2,438
4,747	4,487	-	0%	-		-		-		4,487
1,790	1,615	31	2%	31		-		-		1,584
53,638	**49,996**	**32,040**	**64%**	**27,015**	**84%**	**1,444**	**5%**	**3,581**	**11%**	17,956
577,361	**538,155**	**344,882**		**290,789**		**15,544**		**38,549**		**193,273**

OPTION 2 TOTALS										
				Measured NIA						Not NIA
GEA (approx. sqm)	GIA (approx. sqm)	NIA (approx. sqm)	Nett to Gross	Office		Retail F&B		Other		Service [not NIA]
			% *NIA / GIA*	m2	% of NIA	m2	% of NIA	m2	% of NIA	
-	-	-								-
-	-	-								-
915	853	611	72%							242
2,135	2,073	1,727	83%							346
2,138	2,077	1,731	83%							346
2,358	2,266	1,748	77%							518
3,953	3,832	3,243	85%							588
3,967	3,847	3,146	82%							700
4,029	3,907	3,207	82%							700
4,075	3,953	3,185	81%							768
4,076	3,955	3,158	80%							798
4,099	3,978	3,181	80%							798
4,221	4,099	3,301	81%							798
4,337	4,214	3,416	81%							798
4,353	4,220	3,379	80%							841
4,744	4,595	3,710	81%							885
3,288	3,174	2,341	74%							833
2,162	2,078	1,354	65%							724
4,644	4,477	3,501	78%							976
7,829	7,376	1,742	24%							5,634
4,002	3,618	-	0%							3,618
71,323	**68,593**	**47,682**	**70%**	**41,463**	**87%**	**1,974**	**4%**	**4,257**	**9%**	20,911
767,720	**738,331**	**513,248**		**446,309**		**21,249**		**36,907**		**225,084**

Figure 8—1 Area Schedules received from Sheppard Robson Architects

Option 1

These figures relate to the likely areas of the building at a specific point in time and are subject to change.

Note on area measurements:
These areas have been prepared for the sole use of Sheppard Robson Architects LLP's client and are approximate and can only be verified by a detailed dimensional survey of the completed building.

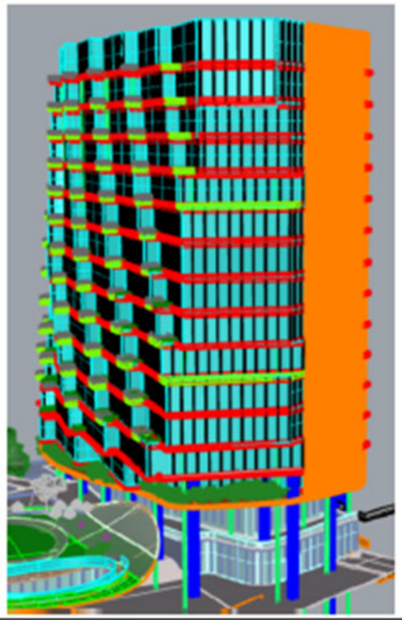
Any decisions to be made on the basis of these predictions, whether as to project viability, pre-letting, lease agreements or otherwise, should include due allowance for the increases and decreases inherent in the design development and building processes. Existing buildings may present anomalies in relation to surveyed/drawn plans that may also affect the stated areas.

All areas are calculated in square metres unless otherwise noted. Where figures are also provided in square feet a conversion factor of 10.764* has been used and the result rounded to the nearest whole number.

Unless otherwise agreed with SR's client in writing, figures relate to the likely areas of the building at the specific stage of the design and are calculated using the RICS Code of Measuring Practice 6th edition 2015.

Appendix A. Whole Life Cycle Carbon Assessment – Key Assumptions

A.3 Example preliminary embodied carbon calculation received from structural engineer



Building Details

Use: *Office*

Approx Construction Value:

Type: *Whole Building*

Study Details

Design Stage: *Concept (RIBA stage 2)*

Carbon Data Region: *UK*

Notes

Calculations carried out in accordance with Istructe How to Calculate Embodied Carbon Guide Rev 1 August 2020.

For carbon factors used refer to page 2. For UK Carbon factors are generally from ICE v 3.0

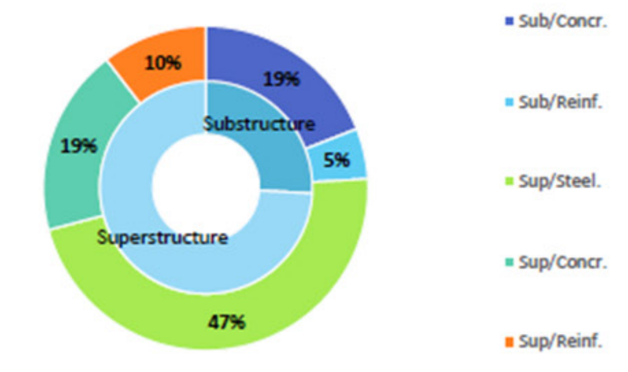
Sequestered Carbon has been recorded as Stored Carbon and is not counted in the basic Embodied Carbon Calculation.

Embodied Carbon Totals

Whole life	10080	tCO_2e	276	$kgCO_2e/m^2$
	Modules A1-A5, C1, C2, C4, D			
To Completion	9281	tCO_2e	254	$kgCO_2e/m^2$
	Modules A1-A5			

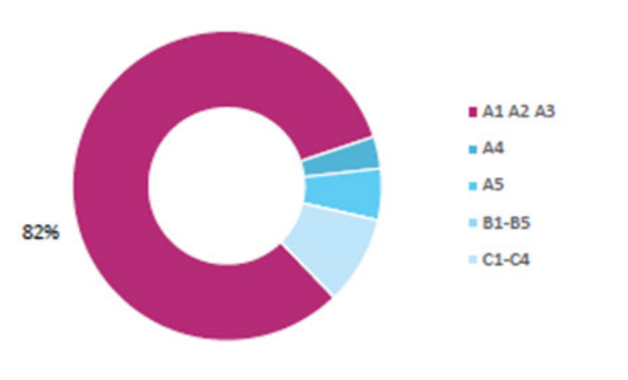
Embodied Carbon Rating: D

$EMbCO_2e$ Material Split (Upfront Carbon)

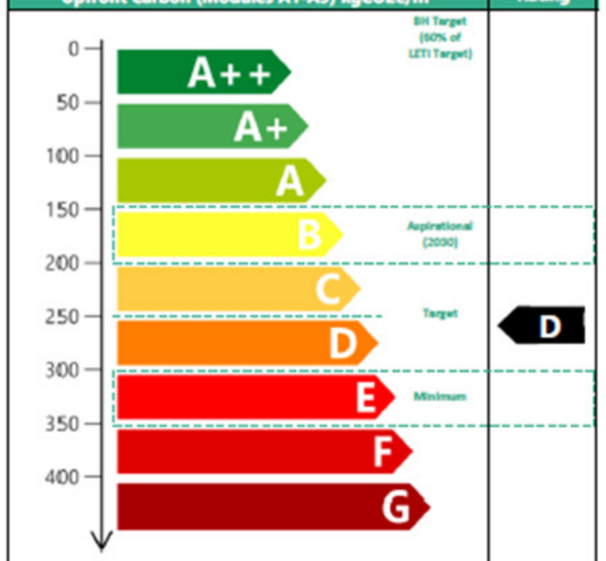


		Total Material Weight t	Embodied Carbon Breakdown tCO_2e						
			Upfront Carbon			Use	End of Life	Total Not incl D	Reuse
			A1 - A3	A4	A5	B1-B5	C1 - C4		D
0. Enabling	Total	0	0	0	0	0	0	0	0
1. Substruc.	Concrete	17005	1513	85	169	0	363	2130	0
	Reinforcement	560	426	18	26	0	12	482	197
	Total:	17565	1939	103	195	0	374	2612	197
2. SuperStruc.	Steel	2080	4222	67	53	0	44	4386	-2000
	Concrete	16680	1485	83	165	0	356	2089	0
	Reinforcement	1156	878	37	54	0	25	994	406
	Total:	19916	6585	187	272	0	425	7469	-1594
6. Modular	Total	0	0	0	0	0	0	0	0
7. Refurb.	Total	0	0	0	0	0	0	0	0
Other	Total	0	0	0	0	0	0	0	0
Totals	Total	37481	8524	290	467	0	799	10080	-1398

Whole Life Carbon Split



Structure $EmbCO_2e$ Rating



Upfront Carbon (Structure) Cradle to Practical Completion (A1-A5) ($kgCO_2e/m^2$)	254
Whole Life Embodied Carbon (Structure) Cradle to Grave (A-C) ($kgCO_2e/m^2$)	276
Module D (Structure) Reuse Potential (A-C) ($kgCO_2e/m^2$)	-38
Sequestered Carbon Stored (Structure) Within Structural Frame at 50yr life (tCO_2e)	0

BURO HAPPOLD

Figure 8—2 Information received from BH structures for Bastion house Option 2

Appendix A. Whole Life Cycle Carbon Assessment – Key Assumptions

A.5 Pro rata values from BH structures information

Preliminary material quantities and specifications were developed for Bastion House by the BH structures team. Values for Rotunda and North Commercial buildings were then pro-rated. Sub-structure was not accounted for in the re-use case as they will be refurbished.

OPTION 2 Bastion House (Received from BH structures)					
GIA m2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1. Substructure	Piles	Concrete - In situ - C32/40 - 50% G	11,690.00	0.32
	1. Substructure	Slabs	Concrete - In situ - C32/40 - 50% G	4,940.00	0.14
	1. Substructure	Column	Concrete - In situ - C32/40 - 50% G	375.00	0.01
	1. Substructure	Reinforcement	Reinforcement - Bars - All Grades - UK Sourced	560.00	0.02
36,586.00					
	2. Superstructure	Frame	Concrete - In situ - C32/40 - 50% G	7,750.00	0.21
	2. Superstructure	Floors	Concrete - In situ - C32/40 - 50% G	6,888.00	0.19
	2. Superstructure	Core slab	Concrete - In situ - C32/40 - 50% G	2,043.00	0.06
	2. Superstructure	Reinforcement	Reinforcement - Bars - All Grades -	1,156.00	0.03
	2. Superstructure	Column	Steel - Hot Rolled - Open Section (A	375.00	0.01
	2. Superstructure	Beams	Steel - Hot Rolled - Open Section (A	1,405.00	0.04
	2. Superstructure	Floors	Steel - Fixings and Sheets - Galvani	300.00	0.01

OPTION 2 Rotunda (Pro-rata values)				
GIA m2	[illegible]	[illegible]	[illegible]	[illegible]
	1. Substructure	Piles	Concrete - In situ - C32/40 - 50% G	8,682.17
	1. Substructure	Slabs	Concrete - In situ - C32/40 - 50% G	3,668.94
	1. Substructure	Column	Concrete - In situ - C32/40 - 50% G	278.51
	1. Substructure	Reinforcement	Reinforcement - Bars - All Grades - UK Sourced	415.91
27,172.45				
	2. Superstructure	Frame	Concrete - In situ - C32/40 - 50% G	5,755.93
	2. Superstructure	Floors	Concrete - In situ - C32/40 - 50% G	5,115.72
	2. Superstructure	Core slab	Concrete - In situ - C32/40 - 50% G	1,517.34
	2. Superstructure	Reinforcemen	Reinforcement - Bars - All Grades -	858.56
	2. Superstructure	Column	Steel - Hot Rolled - Open Section (A	278.51
	2. Superstructure	Beams	Steel - Hot Rolled - Open Section (A	1,043.49
	2. Superstructure	Floors	Steel - Fixings and Sheets - Galvan	222.81

OPTION 2 North commercial (Pro-rata values)					Total
GIA m2	[illegible]	[illegible]	[illegible]	[illegible]	
	1. Substructure	Piles	Concrete - In situ - C32/40 - 50% G	1,004.93	21,377.10
	1. Substructure	Slabs	Concrete - In situ - C32/40 - 50% G	424.67	9,033.61
	1. Substructure	Column	Concrete - In situ - C32/40 - 50% G	32.24	685.75
	1. Substructure	Reinforcement	Reinforcement - Bars - All Grades - UK Sourced	48.14	1,024.05
3,145.11					
	2. Superstructure	Frame	Concrete - In situ - C32/40 - 50% G	666.23	14,172.16
	2. Superstructure	Floors	Concrete - In situ - C32/40 - 50% G	592.13	12,595.85
	2. Superstructure	Core slab	Concrete - In situ - C32/40 - 50% G	175.63	3,735.96
	2. Superstructure	Reinforcemen	Reinforcement - Bars - All Grades -	99.38	2,113.94
	2. Superstructure	Column	Steel - Hot Rolled - Open Section (Al	32.24	685.75
	2. Superstructure	Beams	Steel - Hot Rolled - Open Section (Al	120.78	2,569.28
	2. Superstructure	Floors	Steel - Fixings and Sheets - Galvanis	25.79	548.60

OPTION 1 Bastion House (Pro-rata values)				
GIA m2	[illegible]	[illegible]	[illegible]	[illegible]
14,000.00	2. Superstructure	Frame	Concrete - In situ - C32/40 - 50% G	2,965.62
	2. Superstructure	Floors	Concrete - In situ - C32/40 - 50% G	2,635.76
	2. Superstructure	Core slab	Concrete - In situ - C32/40 - 50% G	781.77
	2. Superstructure	Reinforcement	Reinforcement - Bars - All Grades -	442.35
	2. Superstructure	Column	Steel - Hot Rolled - Open Section (A	143.50
	2. Superstructure	Beams	Steel - Hot Rolled - Open Section (A	537.64
	2. Superstructure	Floors	Steel - Fixings and Sheets - Galvani	114.80

OPTION 1 Rotunda (Pro-rata values)				
GIA m2	[illegible]	[illegible]	[illegible]	[illegible]
	1. Substructure	Piles	Concrete - In situ - C32/40 - 50% G	4,428.56
	1. Substructure	Slabs	Concrete - In situ - C32/40 - 50% G	1,871.44
	1. Substructure	Column	Concrete - In situ - C32/40 - 50% G	142.06
	1. Substructure	Reinforcement	Reinforcement - Bars - All Grades - UK Sourced	212.15
13,860.00	2. Superstructure	Frame	Concrete - In situ - C32/40 - 50% G	2,935.96
	2. Superstructure	Floors	Concrete - In situ - C32/40 - 50% G	2,609.40
	2. Superstructure	Core slab	Concrete - In situ - C32/40 - 50% G	773.96
	2. Superstructure	Reinforcemen	Reinforcement - Bars - All Grades -	437.93
	2. Superstructure	Column	Steel - Hot Rolled - Open Section (A	142.06
	2. Superstructure	Beams	Steel - Hot Rolled - Open Section (A	532.26
	2. Superstructure	Floors	Steel - Fixings and Sheets - Galvan	113.65

OPTION 1 North commercial (Pro-rata values)					Total
GIA m2	[illegible]	[illegible]	[illegible]	[illegible]	
					4,428.56
					1,871.44
					142.06
					212.15
800.00	2. Superstructure	Frame	Concrete - In situ - C32/40 - 50% G	169.46	6,071.04
	2. Superstructure	Floors	Concrete - In situ - C32/40 - 50% G	150.61	5,395.78
	2. Superstructure	Core slab	Concrete - In situ - C32/40 - 50% G	44.67	1,600.40
	2. Superstructure	Reinforcemen	Reinforcement - Bars - All Grades -	25.28	905.56
	2. Superstructure	Column	Steel - Hot Rolled - Open Section (Al	8.20	293.76
	2. Superstructure	Beams	Steel - Hot Rolled - Open Section (Al	30.72	1,100.62
	2. Superstructure	Floors	Steel - Fixings and Sheets - Galvanis	6.56	235.01

Figure 8—3 Pro rata values based on information from BH structures

Ground floor "bowl" and basement emissions were accounted for separately because the calculations were done directly by the BH structures team.

	OPTION 2 Basement (Received from BH structures)						
Bowl	2-storey frame	1,328.00	m2	375.00	kgCO2/m2	498,000.00	kgCO2e
	1-storey basement	336.00	m2	250.00	kgCO2/m2	84,000.00	kgCO2e
					Bowl total	582,000.00	kgCO2e

Option 2 Updated GIA m2	68,567.56

Figure 8—4 kgCO_2e calculations for "Bowl" areas received from BH structures

Appendix A. Whole Life Cycle Carbon Assessment – Key Assumptions

A.7 Façade inputs

Typical materials and quantities for unitized facades were assumed per m² in accordance with BH facades preliminary calculations.

Resource	Quantity	CO_2e	Comment	RICS category	Transport, kilometers		Transport, leg 2, kilometers		Service life	Localisation	Repair/year (B3)	Wastage
NEW Glazed Unitised System (	1 m²	0.47t - ~0%	Created on 16/02/2022,	2.5.1.External enclosing	Data by constituent		0		Data by constituent	Data by constituent	Data by constituent	Data by constituent
Aluminium mullion-transom system, 5	3.3 kg	66kg - ~0%	Frame - Aluminium	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Aluminium mullion-transom system, 5	1.4 kg	28kg - ~0%	Frame - Aluminium	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Aluminium mullion-transom system, 5	0.96 kg	19kg - ~0%	Frame - Aluminium	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Aluminium mullion-transom system, 5	1.7 kg	34kg - ~0%	Frame - Aluminium	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Silicone mastics joinery sealant	0.61 kg	8.7kg - ~0%	Frame - EPDM Gaskets	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Large delivery truck, 9	35	United Kingdom IEA2017	None	10 %
Silicone mastics joinery sealant	0.23 kg	3.3kg - ~0%	Frame - EPDM Gaskets	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Large delivery truck, 9	35	United Kingdom IEA2017	None	10 %
Silicone mastics joinery sealant	0.74 kg	11kg - ~0%	Frame - EPDM Gaskets	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Large delivery truck, 9	35	United Kingdom IEA2017	None	10 %
Plastic profile CR (chloroprene-rub	0.01 kg	0.12kg - ~0%	Frame - Glass Setting block	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Polyamide plastic	0.48 kg	7.8kg - ~0%	Frame - Thermal brakes	2.5.1.External enclosing	110	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Aluminium die-cast parts, 2700 kg/m	0.86 kg	14kg - ~0%	Frame - Aluminium angles	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Aluminium die-cast parts, 2700 kg/m	0.56 kg	8.8kg - ~0%	Frame - Aluminium bracket	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Aluminium die-cast parts, 2700 kg/m	0.22 kg	3.5kg - ~0%	Frame - Aluminium Spigot	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Screws, self-tapping, stainless ste	0.55 kg	7kg - ~0%	Frame - Stainless steel	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	2.5 %
Coated flat glass, max 3210x6000	50 kg	0.12t - ~0%	Double Glazed Unit - Glass	2.6.1.External Windows	300	Carbon only - HGV (all	0	Trailer combination, 40	35	Local, not needed	None	1 %
Butyl rubber, polyisobutylene	0.002 kg	0.01kg - ~0%	Double Glazed Unit - PVB	2.6.1.External Windows	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Stainless steel sheets or plates, 7	0.11 kg	0.66kg - ~0%	Double Glazed Unit -	2.6.1.External Windows	300	Carbon only - HGV (all	0	Trailer combination, 40	35	Local, not needed	None	2.5 %
Waterproofing system, of two compon	0.29 kg	2.5kg - ~0%	Double Glazed Unit -	2.6.1.External Windows	300	Carbon only - HGV (all	0	Large delivery truck, 9	35	Local, not needed	None	10 %
Aluminium sheet, 2700.0 kg/m3	4.7 kg	0.1t - ~0%	Insulated Spandrel -	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Rock wool insulation panels, unface	9 kg	23kg - ~0%	Insulated Spandrel -	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	8 %
PVC Plastisol	2.2 kg	13kg - ~0%	Insulated Spandrel - PVC	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %
Rock wool/mineral wool insulation,	0.19 kg	0.56kg - ~0%	Fire Stop - Siderise product	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	Local, not needed	None	8 %
Aluminium foil, Rockfol SK 18234	0.02 kg	1.5kg - ~0%	Fire Stop - Aluminium foil	2.5.1.External enclosing	300	Carbon only - HGV (all	0	Trailer combination, 40	35	United Kingdom IEA2017	None	7.5 %

Figure 8—5 One Click LCA inputs for unitized façade / m²

After assumptions for material quantities were established, the quantities per m² were multiplied by the façade areas for each option. The same façade build-ups were assumed for both options.

OPTION 1	Façade area update from IES model m2	29,511
OPTION 2	Façade area update from Rhino model m2	28,977

Figure 8—6 Façade area from models

Appendix B. One Click Inputs

B.1 Appendix. Option 1 One click EPD selection

CLASS	MATERIAL	QUANTITY	QTY_TYPE	COMMENT	THICKNESS_MM	ELEMENTCATEGORY	TRANSPORTDISTANCE_KM
BEAM	Hot-dip galvanized structural steel, 7850 kg/m3 (bauforumstahl / Industrieverband Feuerverzinken)	1100.62	ton	Beams	4	214	1500
COLUMN	Hot-dip galvanized structural steel, 7850 kg/m3 (bauforumstahl / Industrieverband Feuerverzinken)	293.76	ton	Column	4	211	1500
EXTERNAL WAL	NEW Glazed Unitised System (Double Glazing)	29511	m2	Created on 16/02/2022, London Wall West		251	
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	97386	kg	Frame - Aluminium extruded split mullion		251	110
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	41315	kg	Frame - Aluminium extruded split transom		251	110
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	28331	kg	Frame - Aluminium extruded full transom		251	110
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	50169	kg	Frame - Aluminium extruded Cover cap		251	110
EXTERNAL WAL	Silicone mastics joinery sealants, 0.3 kg/ml,	18002	kg	Frame - EPDM Gaskets mullion		251	110
EXTERNAL WAL	Silicone mastics joinery sealants, 0.3 kg/ml,	6788	kg	Frame - EPDM Gaskets transom		251	110
EXTERNAL WAL	Silicone mastics joinery sealants, 0.3 kg/ml,	21838	kg	Frame - EPDM Gaskets retention of infills		251	110
EXTERNAL WAL	Plastic profile CR (chloroprene-rubber)	295	kg	Frame - Glass Setting block (aluminium)		251	110
EXTERNAL WAL	Polyamide plastic	14165	kg	Frame - Thermal brakes Polyammide	0.5	251	110
EXTERNAL WAL	Aluminium die-cast parts, 2700 kg/m3	25379	kg	Frame - Aluminium angles		251	300
EXTERNAL WAL	Aluminium die-cast parts, 2700 kg/m3	16526	kg	Frame - Aluminium bracket		251	300
EXTERNAL WAL	Aluminium die-cast parts, 2700 kg/m3	6492	kg	Frame - Aluminium Spigot		251	300
EXTERNAL WAL	Screws, self-tapping, stainless steel (EJOT)	16231	kg	Frame - Stainless steel screws + bolts		251	300
EXTERNAL WAL	Coated flat glass, max 3210x6000 mm, 2500 kg/m3 (Guardian Europe)	1475550	kg	Double Glazed Unit - Glass Heat strenghtned + coating	1	261	300
EXTERNAL WAL	Butyl rubber, polyisobutylene	59	kg	Double Glazed Unit - PVB		261	300
EXTERNAL WAL	Stainless steel sheets or plates, 7900 kg/m3 (Outokumpu Oyj)	3246	kg	Double Glazed Unit - Stainless steel spacer		261	300
EXTERNAL WAL	Waterproofing system, of two components, 1st layer 1L/m2, 2nd layer 0.25L/m2, CoolRoof i-Cure/SikaRoof i-Cure (Sika)	8558	kg	Double Glazed Unit - Structural Silicone SIKA	1.5	261	300
EXTERNAL WAL	Aluminium sheet, 2700.0 kg/m3	138407	kg	Insulated Spandrel - Aluminium sheet 2 mm	1	251	300
EXTERNAL WAL	Rock wool insulation panels, unfaced, 0,032 W/mK, 6.25 m2K/W, 200 mm, 13 kg/m2, Lambda=0.032 W/(m.K), Rockplus Premium Nu 200mm (ROCKWO	265599	kg	Insulated Spandrel - Rockwool 200 mm RW45	200	251	300
EXTERNAL WAL	PVC Plastisol	64924	kg	Insulated Spandrel - PVC spacer		251	300
EXTERNAL WAL	Rock wool/mineral wool insulation, L = 0.035-0.037 W/mK, 33-45 kg/m3, Fire resistance class = A1 (Knauf Insulation (2019))	5607	kg	Fire Stop - Siderise product (dense mineral wool)		251	300
EXTERNAL WAL	Aluminium foil, Rockfol SK 18234 II (ROCKWOOL)	590	kg	Fire Stop - Aluminium foil	0.1	251	300
FOUNDATION	Cut and bent steel rebar products, 7850 kg/m3 (Express Reinforcements)	212.15	ton	Reinforcement		111	110
FOUNDATION	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	1871.44	ton	Slabs	200	113	50
FOUNDATION	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	4428.56	ton	Piles	200	111	50
FOUNDATION	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	142.06	ton	Column	200	214	50
SLAB	Profiled steel decking for composite floor slabs/decking, 0.9mm sheet thickness, 11.35kg/m2, ComFlor 80 0.9mm steel structural floor deck (Tata Steel)	235.01	ton	Floors	0.9	221	110
SLAB	Cut and bent steel rebar products, 7850 kg/m3 (Express Reinforcements)	905.56	ton	Reinforcement		214	110
SLAB	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	1600.4	ton	Core slab	200	221	50
SLAB	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	5395.78	ton	Floors	200	221	50
WALL	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	6071.04	ton	Frame	200	214	50

Appendix B. One Click Inputs

B.3 Appendix. Option 2 One click EPD selection

CLASS	MATERIAL	QUANTITY	QTY_TYPE	COMMENT	THICKNESS_MM	ELEMENTCATEGORY	TRANSPORTDISTANCE_KM
BEAM	Hot-dip galvanized structural steel, 7850 kg/m3 (bauforumstahl / Industrieverband Feuerverzinken)	2569.28	ton	Beams	4	214	1500
COLUMN	Hot-dip galvanized structural steel, 7850 kg/m3 (bauforumstahl / Industrieverband Feuerverzinken)	685.75	ton	Column	4	211	1500
EXTERNAL WAL	NEW Glazed Unitised System (Double Glazing)	28977	m2	Created on 16/02/2022, London Wall West		251	
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	94465	kg	Frame - Aluminium extruded split mullion		251	300
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	40568	kg	Frame - Aluminium extruded split transom		251	300
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	27818	kg	Frame - Aluminium extruded full transom		251	300
EXTERNAL WAL	Aluminium mullion-transom system, 5.7 kg/m	47812	kg	Frame - Aluminium extruded Cover cap		251	300
EXTERNAL WAL	Silicone mastics joinery sealants, 0.3 kg/ml, IMENT A8 PRO WÜRTH MASTIC SILICONE NEUTRE S (SFJF DTSB)	17676	kg	Frame - EPDM Gaskets mullion		251	300
EXTERNAL WAL	Silicone mastics joinery sealants, 0.3 kg/ml, IMENT A8 PRO WÜRTH MASTIC SILICONE NEUTRE S (SFJF DTSB)	6665	kg	Frame - EPDM Gaskets transom		251	300
EXTERNAL WAL	Silicone mastics joinery sealants, 0.3 kg/ml, IMENT A8 PRO WÜRTH MASTIC SILICONE NEUTRE S (SFJF DTSB)	21443	kg	Frame - EPDM Gaskets retention of infills		251	300
EXTERNAL WAL	Plastic profile CR (chloroprene-rubber)	290	kg	Frame - Glass Setting block (aluminium)		251	300
EXTERNAL WAL	Polyamide plastic	13909	kg	Frame - Thermal brakes Polyammide	0.5	251	300
EXTERNAL WAL	Aluminium die-cast parts, 2700 kg/m3	24920	kg	Frame - Aluminium angles		251	300
EXTERNAL WAL	Aluminium die-cast parts, 2700 kg/m3	16227	kg	Frame - Aluminium bracket		251	300
EXTERNAL WAL	Aluminium die-cast parts, 2700 kg/m3	6375	kg	Frame - Aluminium Spigot		251	300
EXTERNAL WAL	Screws, self-tapping, stainless steel (EJOT)	15937	kg	Frame - Stainless steel screws + bolts		251	300
EXTERNAL WAL	Coated flat glass, max 3210x6000 mm, 2500 kg/m3 (Guardian Europe)	1448850	kg	Double Glazed Unit - Glass Heat strenghtned + coating	1	261	300
EXTERNAL WAL	Butyl rubber, polyisobutylene	58	kg	Double Glazed Unit - PVB		261	300
EXTERNAL WAL	Stainless steel sheets or plates, 7900 kg/m3 (Outokumpu Oyj)	3187	kg	Double Glazed Unit - Stainless steel spacer		261	300
EXTERNAL WAL	Waterproofing system, of two components, 1st layer 1L/m2, 2nd layer 0.25L/m2, CoolRoof i-Cure/SikaRoof i-Cure (Sika)	8403	kg	Double Glazed Unit - Structural Silicone SIKA	1,5	261	300
EXTERNAL WAL	Aluminium sheet, 2700.0 kg/m3	135902	kg	Insulated Spandrel - Aluminium sheet 2 mm	1	251	300
EXTERNAL WAL	Rock wool insulation panels, unfaced, 0,032 W/mK, 6.25 m2K/W, 200 mm, 13 kg/m2, Lambda=0.032 W/(m.K), Rockplus Premium Nu 200mm (ROCKW	260793	kg	Insulated Spandrel - Rockwool 200 mm RW45	200	251	300
EXTERNAL WAL	PVC Plastisol	63981	kg	Insulated Spandrel - PVC spacer		251	300
EXTERNAL WAL	Rock wool/mineral wool insulation, L = 0.035-0.037 W/mK, 33-45 kg/m3, Fire resistance class = A1 (Knauf Insulation (2019))	5506	kg	Fire Stop - Siderise product (dense mineral wool)		251	300
EXTERNAL WAL	Aluminium foil, Rockfol SK 18234 II (ROCKWOOL)	580	kg	Fire Stop - Aluminium foil	0.1	251	300
FOUNDATION	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	21377.1	ton	Piles	200	111	50
FOUNDATION	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	9033.61	ton	Slabs	200	113	50
FOUNDATION	Cut and bent steel rebar products, 7850 kg/m3 (Express Reinforcements)	1024.05	ton	Reinforcement		111	110
FOUNDATION	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	685.75	ton	Column	200	214	50
SLAB	Profiled steel decking for composite floor slabs/decking, 0.9mm sheet thickness, 11.35kg/m2, ComFlor 80 0.9mm steel structural floor deck (Tata Steel)	548.6	ton	Floors	0.9	221	110
SLAB	Cut and bent steel rebar products, 7850 kg/m3 (Express Reinforcements)	2113.94	ton	Reinforcement		214	110
SLAB	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	3735.96	ton	Core slab	200	221	50
SLAB	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	12595.85	ton	Floors	200	221	50
WALL	Ready-mix concrete, normal strength, generic, C32/40 (4600/5800 PSI) with CEM III/A, 50% GGBS content (320 kg/m3; 20 lbs/ft3 total cement)	14172.16	ton	Frame	200	214	50

Appendix C. Operational Carbon Assessment Assumptions

C.1 Building Operational Energy Inputs

Building elements U-value (W/m2K)	Re-use option	Re-development option
External wall	0.26	0.26
Exposed floor	0.22	0.22
Roof	0.20	0.18
New façade	1.3	1.3
New glass	1.5	1.5
g-value (new glass)	0.21-0.33	0.21-0.33
Replaced glass	1.5	n/a
Re-cladding façade (only for re-use option)	1.6	n/a
g-value (only for upgraded glazing elements)	0.40	n/a
Existing curtain wall system	3.2	n/a
Existing glass	5.5	n/a
g-value (existing glass)	0.73	n/a
Air-permeability	8 (m3/h m2 @50Pa) with recladding	3 m3/h.m2@50Pa

Figure 8—7 Building operational energy inputs

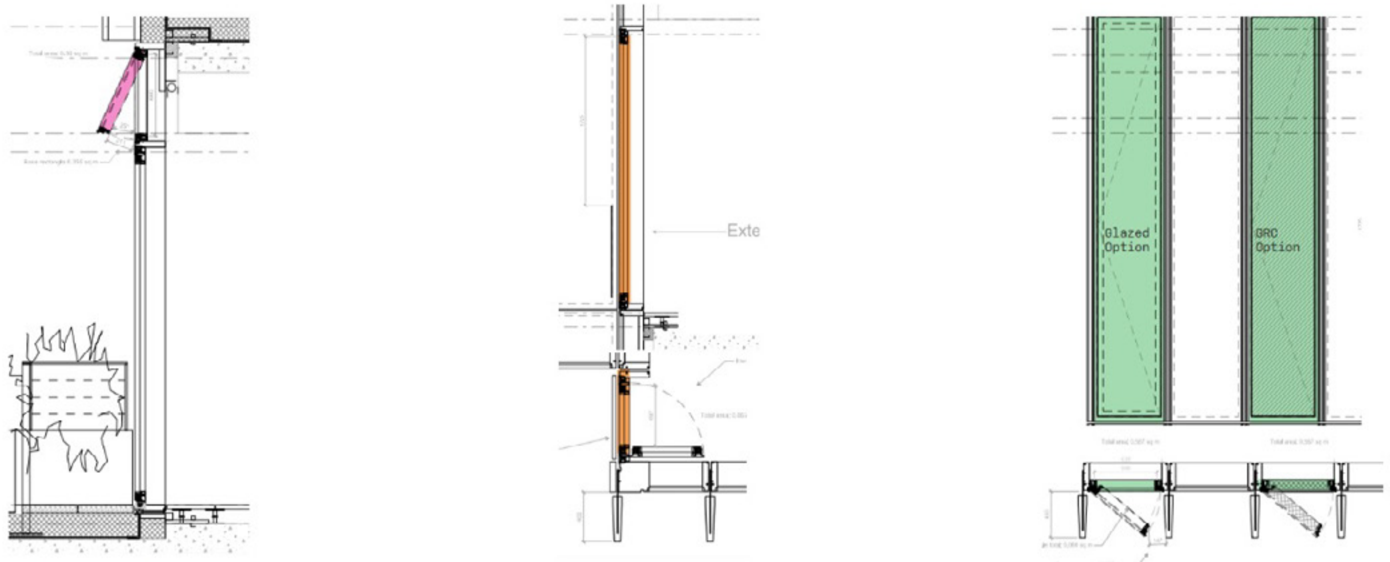
C.2 Building Operational Energy (MEP) Inputs

	Units	New build	Re-use
System	-	Centralised full fresh air (15 l/s/p)	Centralised full fresh air (15 l/s/p)
Heating			
Fuel	-	electricity	electricity
Generator	-	ASHP	ASHP
Emitter	-	Trench heaters/Supply Air diffuser/Rads BoH	Trench heaters/Supply Air diffuser/Rads BoH
Heating SCOP	Kw/Kw	SCOP 3.2	SCOP 3.2
LTHW Pumping	-	Variable pumping flow rate	Variable pumping flow rate
Cooling			
Fuel	-	electricity	electricity
Generator	-	Chillers	Chillers
Emitter	-	Supply air diffuser	Supply air diffuser
Cooling Seasonal Efficiency	Kw/Kw	SEER 4.6	SEER 4.6
Terminal Unit SFP	W/l/s	0.25 for fan coil units	0.25 for fan coil units
System control	-	Central Time control	Central Time control
		Optimum start/stop control	Optimum start/stop control
		Local temperature control	Local temperature control
		Weather Compensation Control	Weather Compensation Control
System metering	-	Extensive to meet BREEAM outstanding credits, all mech plant, and all floors for tenants anyway.	
Ventilation			
AHU system		centralised system	centralised system
Local extract rate	ACH	4 ach for boH and 6ach for WC	4 ach for boH and 6ach for WC
Local extract SFP	W/l/s	0.3	0.3
Central AHU SFP	W/l/s	1.6	1.6
Heat Recovery Efficiency	%	85% typically, we can push for even higher from good manufacturers	
Vent. Control	-	Valves on floor, temp and Co2 sensors on floor	
Ventilation strategy	-	Mixed mode ventilation applied only to top-levels of Rotunda and Bastion House (5ht to 11th floor)	
PV technology			
PV module	1.6		1.6
N panels	248		248
Effective PV area	396.8		396.8
Slope	12 deg		12 deg
module efficiency	0.2		0.2

Figure 8—8 Building Operational Energy (MEP) Inputs

Appendix C. Operational Carbon Assessment Assumptions

C.3 Mixed mode assumptions for a typical floorplan



- Vent size: 740x1295mm
- Restrictor length 210mm
- Total free area: 0.30sqm
- Top hung/Outward opening

- Vent size: 560x2705mm
- Restrictor length: 211mm
- Total free area: 0.86sqm
- Side hung/Inward opening @90deg

- Vent size: 630x3890mm
- Restrictor length: 135mm
- Fin depth: 400mm
- Front clearance: 0.567sqm
- Side hung/outward opening

Figure 8—9 Vent types in the mixed mode strategy

Mixed mode strategy				
Opening type	Façade Average U-values (W/m2 K)	Control and operation of vents1	free area per vent (sqm)	No Vent
Window above the door (Façade with small, glazed vent above the door)		Top hung vent Automatic control from room temperature and CO2 levels.	0.30	6
Husk façade reveals (Façade with large glazed/GRC faced vent)	1.7	Operable door with spandrel above (side-hung door). The openings are controlled from room temperature and CO2 level.	0.86	5
Husk façade with external fins (façade with full height glazed vent and fins)		Facade with full height operable panels and fins. The openings are controlled from room temperature and CO2 level	0.57	32

1 Vent/door type are controlled automatically to open when space temperatures are between 22°C and 25°C, If outside temperature<18°C, vents remain shut to prevent risk of condensation (this value could be lowered to 16°C subject to a risk analysis).

Appendix D. Preliminary Construction Waste Estimate

The following represents an initial estimate, for comparative purposes, of the material arising from construction and demolition (or refurbishment) of the two options under consideration to provide input to the Whole Lifecycle Carbon Assessment.

It should be noted that procurement of an independent pre-development audit is underway, to establish in more detail the amount, type and quality of material in the existing buildings across the site, to help inform the strategy for reuse, refurbishment, deconstruction, recycling and recovery of all materials (either on- or off-site).

A complete assessment covering waste will be provided for the planning submission.

D.1 Policy

The following policy from the Greater London Authority is relevant to the generation, storage and treatment of materials arising from construction, refurbishment, demolition and excavation activities.

The London Plan: Spatial Development Strategy for Greater London (Mayor of London, 2021) – The London Plan includes statutory guidance on how waste, including CD&E waste, should be dealt with as London develops. The plan aims for the equivalent of 100% of London's waste to be managed within London by 2026. Specific objectives relating to CD&E waste are contained within Policy SI7, including the following:

- Industry should collaborate to promote a more circular economy that improves resource efficiency and innovation to keep products and materials at their highest use for as long as possible
- Reusing, recycling or recovering 95% of construction and demolition waste
- The use of 95% of excavation waste for beneficial use (such as providing environmental benefits or the restoration of landfill sites).

Circular Economy Statement Guidance, Pre-consultation Draft (Mayor of London, 2020) – This guidance document explains how to prepare a Circular Economy Statement as required by draft London Plan Policy SI7. The document is still undergoing a consultation process. Regarding CD&E waste, the following commitments are relevant:

- Commitment 1.1 – Minimise the quantity of materials used by considering opportunities to reduce demand for building materials, primarily by questioning the design brief and if it can be met by building less and building more efficiently
- Commitment 2.1 – Design for longevity, adaptability or flexibility and reusability or recoverability. The design process should include a realistic assessment of the ability of the development to accommodate change, how frequently it will be reconfigured / remodelled, and how to avoid a premature end of life for components
- Commitment 2.2 – Design out construction, demolition, excavation and municipal waste arising. For example, through the use of minimisation of packaging, off cuts, damage and rework should be given special attention through off-site, precision manufacture, just-in- time delivery and secure on-site storage. When excavating and designing the public realm, topsoil must be given special attention due to its high value and concerns that it is being damaged and wasted at a highly unsustainable rate. Topsoil should never be disposed of to landfill except potentially as a planting medium as part of a site reclamation scheme. Consideration should be given to balancing cut and fill (avoiding any import or export of material) and to techniques that clean and enable reuse of excavation material on site
- Commitment 3.1 – Managing demolition waste. In order to manage demolition waste, applicants must consider an independent pre-demolition audit, implementing careful demolition strategies, segregating materials and conducting analysis / monitoring of waste flows to maximise reuse and reclamation
- Commitment 3.2 – Managing excavation waste. Due to the characteristics of this waste stream, not all of it can easily be reused or recycled, whether on site, locally or otherwise. Nonetheless, excavation material should be put to the best environmental use that is practicable
- Commitment 3.3 – Managing construction waste. Applicants should aim to incorporate measures for managing construction waste that go above and beyond standard practice where possible. It is also important to recognise that construction waste arises after the initial construction phase of a development – during the operational phase, due to maintenance, refurbishment, and at the end of life. It may be possible to develop plans for managing this waste, based on repair and replacement forecasts or functional adaptability studies.

Appendix D. Preliminary Construction Waste Estimate

D.2 Data Used for Estimation

	Option 1	Option 2	Source
Demolished GEA Existing Total [m^2]	16,858	33,716	BH sheet: LWW-211216-WLC_Inputs_Results.xlsx
Constructed GEA (New Retail) [m^2]	-	2,951	
Constructed GEA (New Office) [m^2]	36,344	61,987	
Constructed GEA (New Leisure) [m^2]	-	6,364	
Constructed GEA (Refurb Office) [m^2]	22,255	-	
Demolition arisings [kg/m^2]	805	805	Villoria-Saez, P., Porras-Amores, C. and del Rio Merino, M. (2020) Advances in Construction and Demolition Waste Recycling
Construction arisings (New Retail) [t/100m^2]	27.5	27.5	BRE (2012) SMARTWaste: BRE Benchmark Data and LOR Construction Management Plan
Construction arisings (New Office) [t/100m^2]	23.8	23.8	BRE (2012) SMARTWaste: BRE Benchmark Data and LOR Construction Management Plan
Construction arisings (New Leisure) [t/100m^2]	21.6	21.6	BRE (2012) SMARTWaste: BRE Benchmark Data and LOR Construction Management Plan
Construction arisings (Refurb Office) [t/100m^2]	23.8	23.8	BRE (2009) Refurbishment Waste Benchmarking Report

D.3 Generation estimation

An initial estimate of material tonnages arising from construction activities, based on the benchmarks set out above, is shown in the following table.

Waste Generated Through -	**Option 1**	**Option 2**
Demolition [t]	13,571	27,141
Construction [t]	8,390	16,660
Excavation [t]	n/a	To be confirmed
Refurbishment [t]	5,138	-
Total [t]	**27,099**	**43,801**

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