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Whole Life Cycle Carbon Emissions Assessment

SHH Architecture

14 Greenaway Gardens

Final

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ABOUT HODKINSON CONSULTANCY

Our team of technical specialists offer advanced levels of expertise and experience to our clients. We have a wide experience of the construction and development industry and tailor teams to suit each individual project.

We are able to advise at all stages of projects from planning applications to handover.

Our emphasis is to provide innovative and cost-effective solutions that respond to increasing demands for quality and construction efficiency.

Executive Summary

This Whole Life Cycle Carbon Emissions (WLCCE) Assessment for the proposed development at 14 Greenaway Gardens in the London Borough of Camden, has been prepared by Hodkinson Consultancy, a specialist energy and environmental consultancy for planning and development.

To support Camden Council in fully understanding the impacts of this proposed development, this report will identify the potential carbon that will be produced over a 60-year period.

National Building Regulations and the Mayor's net zero-carbon target for new development account for a building's operational carbon emissions. As methods and approaches for reducing operational emissions have become better understood, and as targets have become more stringent, these emissions are now beginning to make up a declining proportion of a development's carbon emissions. Attention now needs to turn to WLCCE to incorporate embodied carbon emissions, enabling a better understanding of the environmental impact of the proposed development.

WLCCE are the carbon emissions resulting from the construction and the use of a building over its entire life, through four stages described as life-cycle modules, shown in Figure i below.

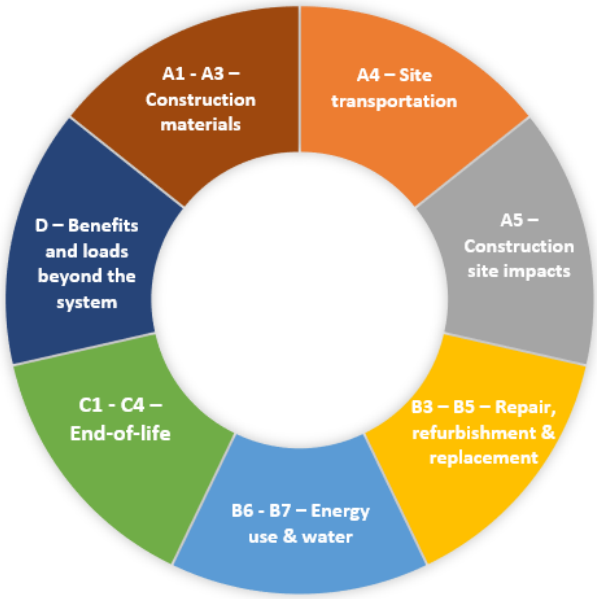

Figure i: Life cycle modules

They capture a building's operational carbon emissions from both regulated and unregulated energy use, as well as its embodied carbon emissions. Embodied emissions are those associated with raw material extraction, manufacture and transport of building materials, construction and the emissions associated with maintenance, repair, and replacement as well as dismantling, demolition, and eventual material disposal. The assessment provides a picture of a building's carbon impact on the environment.

The following table outlines the assumptions made within this WLCCE assessment:

Table i: WLCCE assumptions

Data	Data source
Material types and volumes (A1-A3)	Where possible, material types were taken from floor plans, provided by the applicant.
Transport data (A4)	Default values provided by One Click.
Construction site impacts (A5)	Construction value provided by applicant for the scenarios modelled.
Repair and Replacement data (B3-B4)	Default values provided by RICS and One Click EPD database for products.
Operational energy (B6)	Regulated and unregulated values were provided by ME7 Ltd (May 2022). The same strategy was applied across the three proposed Options.
Operational water (B7)	Water consumption based on Building Regulations Part G 'Enhanced Consumption' of 110 l/pp/d and multiplied by the intended full occupancy of the development (residential).
End of life (C1-C4)	Default values provided by One Click based on the information within the EPD database. Note that One Click reports all module C emissions as one figure, it is not yet able to split them across C1-C4.
Building areas	Building rebuild and refurbishment areas taken from the accommodation schedule provided by the applicant.
Number of occupants	8 occupants, taken from accommodation schedule
Assessment period	60 years

The total $kgCO_2$ demonstrate that the lowest emissions are emitted from Option 3. This is expected to emit the least emissions over a 60 year period, as shown in Table ii below.

Table ii: Total $kgCO_2$ per proposed option

Proposed Option	Total net $kgCO_2$	Total net $kgCO_2/m^2$
Option 1 - Basement extension only	**3,086,661**	**5,947**
Option 2 – Internal retrofit	**1,463,100**	**1,457**
Option 3 – Internal retrofit and partial reconstruction	**1,413,767**	**1,408**

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CONTENTS

1. INTRODUCTION

1.1 This Whole Life Cycle Carbon Emissions (WLCCE) Assessment has been prepared by Hodkinson Consultancy, a specialist energy and environmental consultancy for planning and development for the proposed development at 14 Greenaway Gardens.

1.2 National Building Regulations and the Mayor's net zero-carbon target for new development account for a building's operational carbon emissions. As methods and approaches for reducing operational emissions have become better understood, and as targets have become more stringent, these emissions are now beginning to make up a declining proportion of a development's carbon emissions. Attention now needs to turn to WLCCE to incorporate embodied carbon emissions, enabling a better understanding of the environmental impact of the proposed development.

1.3 To support Camden Council in fully understanding the impacts of this proposed development, this report will identify the carbon that will be emitted from the following options (an overview of these have been provided in Figure 1):

- **Option 1:** Basement extension only.
    - This option involves the retention of the existing house in its current state with no retrofitting, and a new regulations-compliant basement constructed underneath.
- **Option 2:** Internal retrofit.
    - This option looks at the retention and repointing of all existing external walls, the addition of high performing internal insulative lining, and the creation of a new roof and compliant basement.
    - The treatment of the existing walls consists of repointing the existing brickwork, the addition of a 40mm of mineral wool between battens, 100mm of PIR insulation, and 12mm of plasterboard. The same energy strategy for Option 2 has also been applied to Option 3, which includes low u-values and a ground source heat pump.
- **Option 3:** Internal retrofit and partial reconstruction
    - This option involves a combined approach whereby some existing external walls are retained, and some are rebuilt in a more energy efficient build up. The external walls chosen for retention are those deemed to be a positive contributor to the conservation area. Much of the areas of wall to be rebuilt have already undergone alterations over the past decades. The retention of the south and east elevations and front portions of the west and north façade allow for 89.2% of the original external wall that is visible from the public realm to be preserved.

> The build-up for the proposed rebuilt walls involves a 215mm brick wall constructed from reclaimed bricks, a cavity break, vapour barrier, 190mm of rockwool insulation between studs, 9mm of OSB and 12mm of plasterboard. Option 3 will ensure that as much material as possible will be reclaimed and reused from the deconstructed elements, including brickwork, roof tiles and timber.

> The same energy strategy for Option 3 has also been applied to Option 2, which includes low u-values and a ground source heat pump.

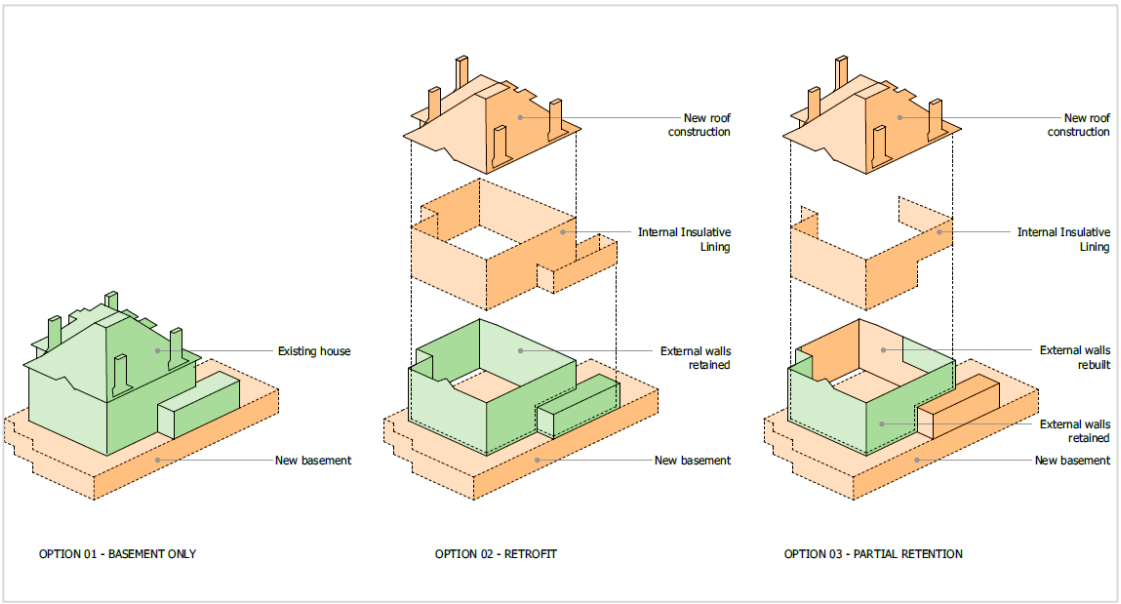

Figure 1: Proposed options for 14 Greenaway Gardens

2. DEVELOPMENT OVERVIEW

Site Location

2.1 The proposed development site at 14 Greenaway Gardens is located in Hampstead, as shown in Figure 2 below.

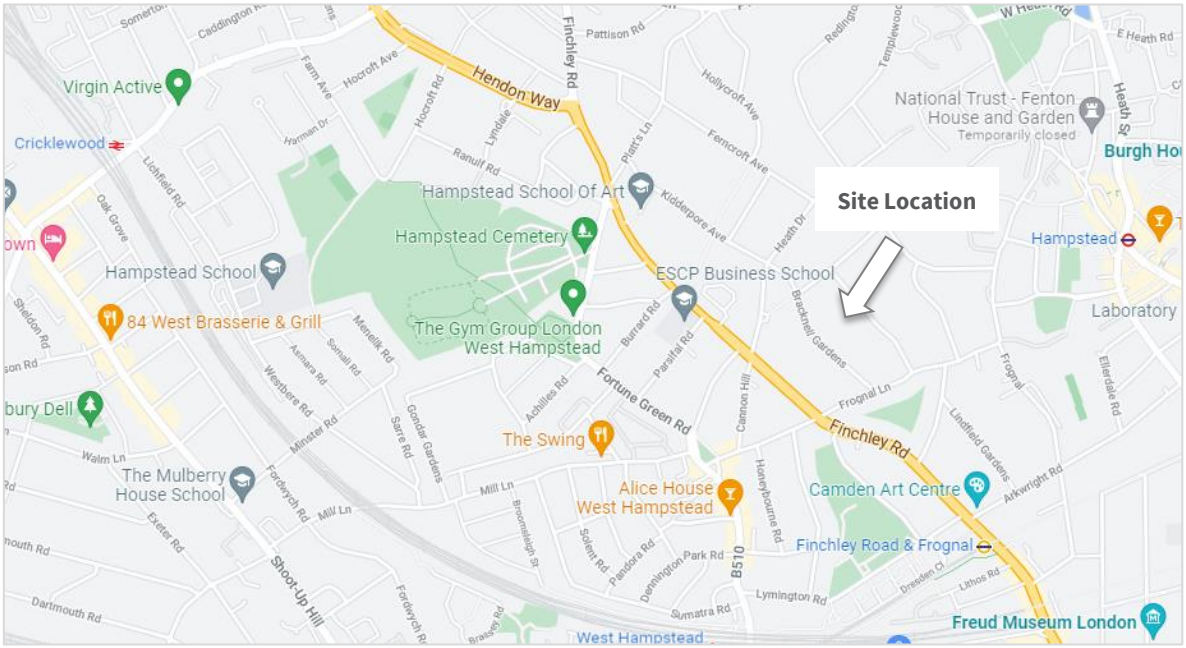

Figure 2: Site Location (Google Maps, 2021)

2.2 Greenaway Gardens was built in 1922 through the grounds of Frognal Park. Camden Council have noted that the building is a positive contributor to the character and appearance of the conservation area, which the Council has a statutory obligation to preserve or enhance.

Proposed Development

2.3 The proposed development is described as follows:

"Partial demolition of existing dwelling with retention of the front facade and parts of the side and rear facades (which are to be restored) and the erection of a basement extension, infill rear extension, various minor changes to the fenestration and other associated works."

2.4 Figure 3 below illustrates the proposed site layout.

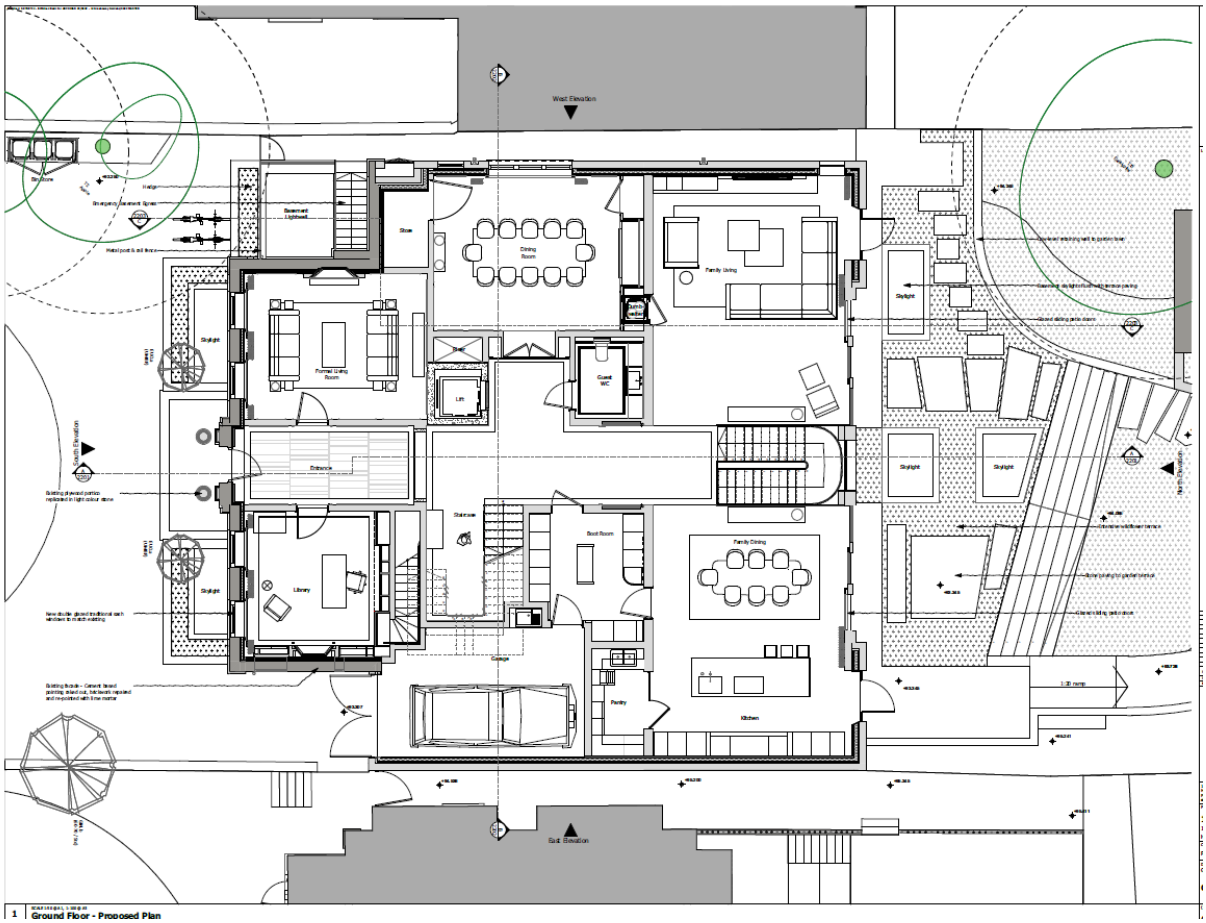

Figure 3: Proposed Site Layout (SHH Architecture, May 2022)

3. POLICY AND REGULATIONS

Regional Policy: The London Plan

London Plan (2021)

3.1 The London Plan sets out an integrated economic, environmental, transport and social framework for the development of London:

Policy SI 2 Minimising Greenhouse Gas Emissions, states:

> *'Development proposals referable to the mayor should calculate whole life-cycle carbon emissions through a nationally recognised Whole Life-Cycle Carbon Assessment and demonstrate actions*

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

3.2 The proposed development is not referable and as such, is not required to undertake a WLCCE assessment. However, the applicant has opted to undertake one to demonstrate the environmental impact of the proposed works. The Greater London Authority have released guidance *"Whole Life-Cycle Carbon Assessments guidance – March 2022".* It outlines how to prepare a WLCCE assessment.

4. WHOLE LIFE CYCLE CARBON EMISSIONS ASSESSMENT

4.1 Undertaking WLCCE assessments is a way to fully understand and minimise the carbon emissions associated with building designs over the entire life cycle of the building. This will be done to quantify the WLCCE that will be released from the proposed development, considering not only operational and embodied emissions but also demolition, construction, and refurbishment/replacement cycles.

4.2 WLCCE encompass both embodied and operational carbon:

> **Operational carbon** is the energy required to heat and power a building.

> **Embodied carbon** is the carbon that is released in the manufacturing, production, and transportation of the building materials used.

4.3 In addition to the two metrics above there are additional life cycle stages that are considered during WLCCE assessments, these include demolition, end of life and refurbishment/replacement cycles.

4.4 The two metrics (operational and embodied) and the additional life cycle stages, as noted above, have been included in this WLCCE assessment.

4.5 Undertaking a WLCCE assessment provides a full overview of the material and construction of a building using science-based metrics whilst also identifying the overall best combined opportunities for reducing lifetime emissions, and helps to avoid any unintended consequences of focusing on operational emissions alone.

Methodology

4.6 To support Camden Council in fully understanding the impacts of this proposed development, this report will identify the carbon that will be emitted from the following options:

- **Option 1:** Basement extension only.
  - This option involves the retention of the existing house in its current state with no retrofitting, and a new regulations-compliant basement constructed underneath.
- **Option 2:** Internal retrofit
  - This option looks at the retention and repointing of all existing external walls, the addition of high performing internal insulative lining, and the creation of a new roof and compliant basement.
  - The treatment of the existing walls consists of repointing the existing brickwork, the addition of a 40mm of mineral wool between battens, 100mm of PIR insulation, and 12mm of plasterboard. The same energy strategy for Option 2 has also been applied to Option 3, which includes low u-values and a ground source heat pump.
- **Option 3:** Internal retrofit and partial reconstruction
  - This option involves a combined approach whereby some existing external walls are retained, and some are rebuilt in a more energy efficient build up. The external walls chosen for retention are those deemed to be a positive contributor to the conservation area. Much of the areas of wall to be rebuilt have already undergone alterations over the past decades. The retention of the south and east elevations and front portions of the west and north façade allow for 89.2% of the original external wall that is visible from the public realm to be preserved.
  - The build-up for the proposed rebuilt walls involves a 215mm brick wall constructed from reclaimed bricks, a cavity break, vapour barrier, 190mm of rockwool insulation between studs, 9mm of OSB and 12mm of plasterboard. Option 3 will ensure that as much material as possible will be reclaimed and reused from the deconstructed elements, including brickwork, roof tiles and timber.
  - The same energy strategy for Option 3 has also been applied to Option 2, which includes low u-values and a ground source heat pump.

4.7 Refer to Figure 1 on page 8 for an overview of these.

Study Period

4.8 The reference study period (RSP) is 60 years, this is based on the principles outlined in BS EN 15978: 2011, section 7.3 and the RICS guidance. RSPs are fixed to enable comparability between whole life carbon results for different projects. It ensures that the assessment is representative of typical service life of different building elements.

Operational Carbon

4.9 Operational energy is the inputted energy required for all heating and power needs. It can be split into two variants (both are included in this assessment):

> **Regulated emissions** - which are assessed using the Government's approved methodology for Building Regulations Part L compliance, the Standard Assessment Procedure (SAP) for residential units; and

> **Unregulated emissions** – energy use as a direct result of user behaviour. This includes cooking, white goods (fridges, washing machines, etc), and plug-in electrical loads (televisions, laptops, lamps, etc).

4.10 The unregulated energy demands for the Proposed Development have been calculated using the methodology outlined in the SAP 2012 document. This calculates the CO_2 emissions associated with appliances and cooking. For clarity, as unregulated energy demands are largely reliant on the behaviour of occupants, they have been considered a fixed entity in the calculations for the proposed options in accordance.

Embodied Carbon

One Click LCA

4.11 OneClick LCA is the software that has been used to conduct the WLCCE assessment. This is a web based piece of design software for buildings and infrastructure approved for use by the GLA. OneClick LCA consists of a large database of generic and average Life Cycle Indicator (LCI) data, and global Environmental Product Declaration (EPDs).

4.12 The most suitable option for each material (where available) was chosen from the database in OneClick. The material LCI data has been chosen to be representative of the typical UK supply chain. The life cycle stages (or modules) included within the WLCCE assessment as standard are shown in Figure 4 below.

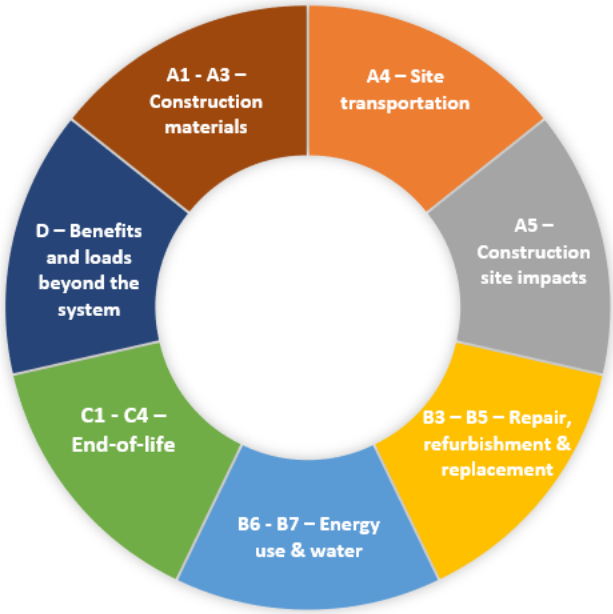

Figure 4: Life cycle stages

4.13 At this stage it is not expected that all the information will be available. Where this is the case, One Click has been used. As the design develops, we will update and refine the tool to reflect the quantity and types of materials being used.

Construction Impacts

4.14 In addition to embodied carbon in the materials used for construction, greenhouse gas (GHG) emissions will be created by transportation of materials to site and operation of onsite plant and machinery. Guidance from RICs indicates 1.4 tonnes of CO_2e per £100,000 of project value, this is further referenced and approved by the BRE.

4.15 The project value has been provided by the Applicant, which would result in construction transport GHG emissions of:

> **Option 1:** 98 tonnes of CO_2

> **Option 2:** 154 tonnes of CO_2

> **Option 3:** 140 tonnes of CO_2

4.16 Further construction impacts (temporary piling and temporary steel supports) based on the floor area have also been applied to all options.

Potable Water Use

4.17 The carbon impact associated with water use during the operation of the proposed development is also required to be reported, in accordance with the RICS guidance. Water consumption is based on Building Regulations Part G 'enhanced consumption' of 110 litres/per person/per day (including external water use) and multiplied by the intended full occupancy of the development annually.

4.18 For all options, 8 occupants have been estimated using the number of expected inhabitants of the dwelling from the accommodation schedule. This gives an estimated **annual water consumption of 321 m³** for the entire development for 60 years.

Data Sources

4.19 The assessment has used multiple data sources described above and is based on the level of detail available at the current stage of design. The following data sources have been used:

Table 1: Data Sources

Data	Data source
Material types and volumes (A1-A3)	Where possible, material types were taken from floor plans, provided by the applicant.
Transport data (A4)	Default values provided by One Click.
Construction site impacts (A5)	Construction value provided by applicant for the scenarios modelled.
Repair and Replacement data (B3-B4)	Default values provided by RICS and One Click EPD database for products.
Operational energy (B6)	Regulated and unregulated values were provided by ME7 Ltd (May 2022). The same strategy was applied across the three proposed Options.
Operational water (B7)	Water consumption based on Building Regulations Part G 'Enhanced Consumption' of 110 l/pp/d and multiplied by the intended full occupancy of the development (residential).
End of life (C1-C4)	Default values provided by One Click based on the information within the EPD database. Note that One Click reports all module C emissions as one figure, it is not yet able to split them across C1-C4.
Building areas	Building rebuilds and refurbishment areas taken from the accommodation schedule provided by the applicant.
Number of occupants	8 occupants, taken from accommodation schedule
Study period	60 years

4.20 For clarity, all assumptions made within the WLCCE assessment have been noted within this report. The assessment and comments made throughout should be taken within the context of carbon and energy use only.

5. WHOLE LIFE CYCLE CARBON RESULTS

5.1 Figure 5 overleaf outlines the expected kg CO_2 (net) emissions that the three proposed options are expected to emit over a 60-year period.

5.2 The total kgCO_2 demonstrate that the lowest emissions are emitted from Option 3, this is expected to emit the least emissions over a 60-year period, as shown in Table 2.

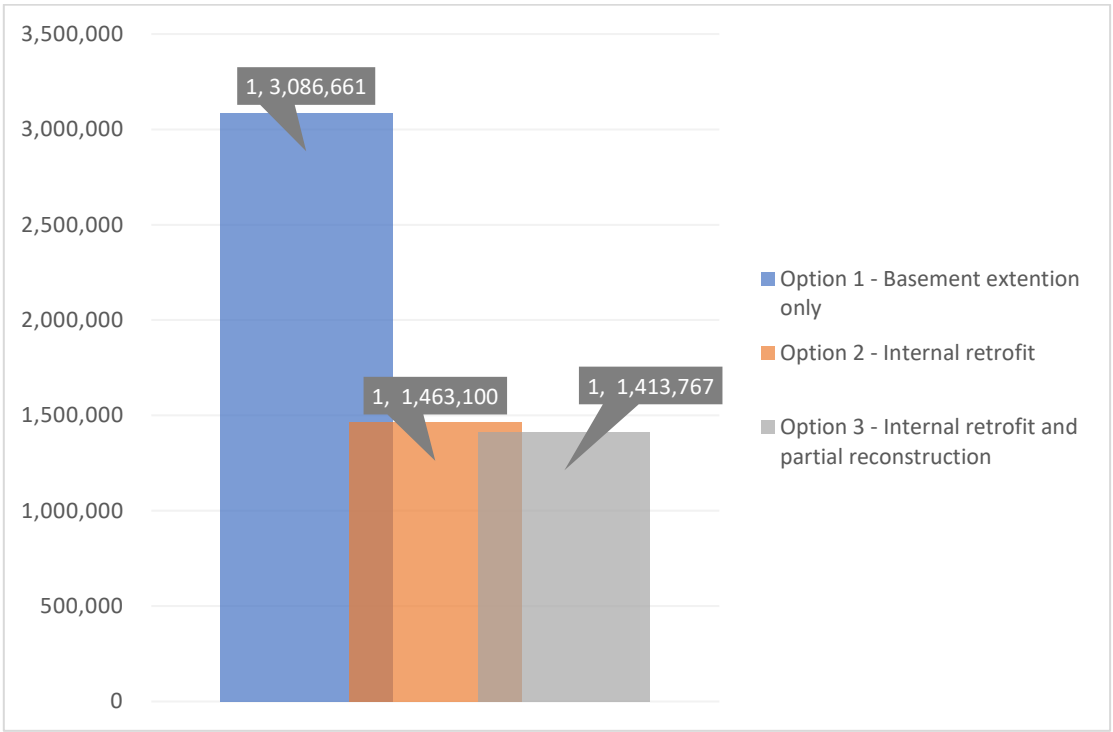

Figure 5: Total kgCO_2/60 years for options proposed

Table 2: Total $kgCO_2$ per proposed option

Proposed Option	Total net $kgCO_2$	Total net $kgCO_2/m^2$
Option 1 - Basement extension only	**3,086,661**	**5,947**
Option 2 – Internal retrofit	**1,463,100**	**1,457**
Option 3 – Internal retrofit and partial reconstruction	**1,413,767**	**1,408**

Option One

5.3 This option involves no work undertaken on the main house. The basement will be designed to minimum building regulations.

5.4 The use of cement replacement products allows for a lower carbon concrete with 60% CO_2 reduction in comparison to standard CEM I concrete have been allowed for. The emissions for this option are entirely under A1-A3 for the materials used in the basement, operational energy for the proposed basement (B6) and some construction impacts (A5).

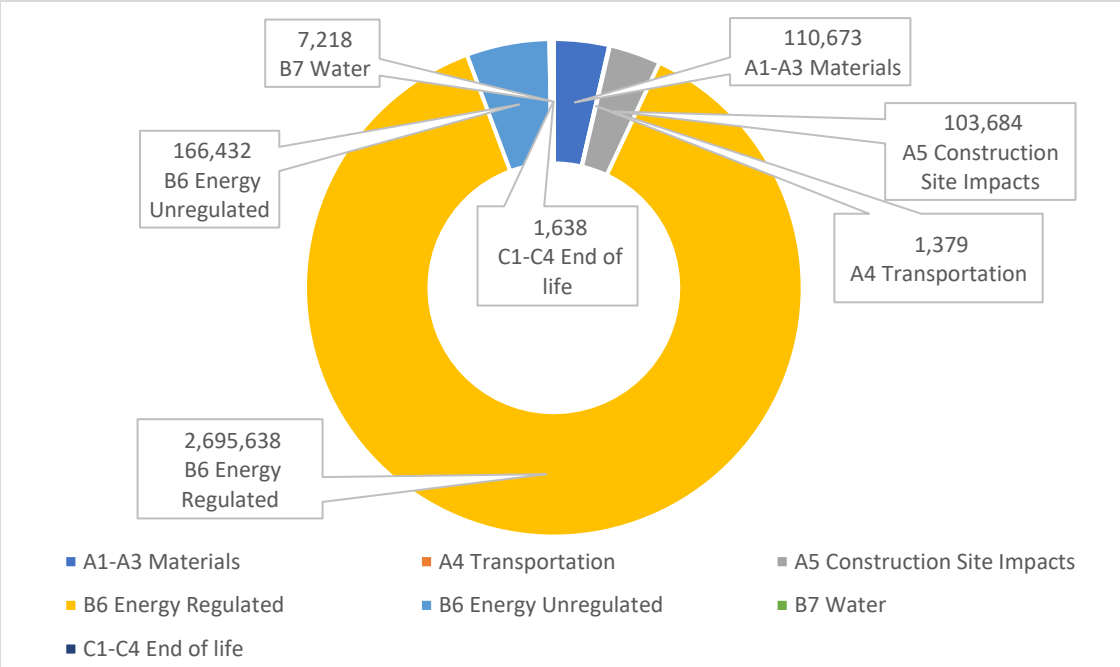

Figure 6: Option 1 - total $kgCO_2$ / 60 years – Life cycle emissions

Option Two

5.5 This option involves a comprehensive refurbishment of the existing development. Including retention and repointing of all existing external walls, the addition of high performing internal insulative lining, and the creation of a new roof and compliant basement.

5.6 The increased emission to this option is due to the extensive works required to achieve the required u-values which ensure that relevant Building Regulation standards are met. The addition of a 40mm of mineral wool between battens, 100mm of PIR insulation, and 12mm of plasterboard increases the embodied carbon significantly.

5.7 The low carbon energy strategy for Option 3 has been modelled in Option 2, the emissions for B6 are the same for both options. However, it must be noted that significantly more materials are required in this Option to get the u-value required to achieve these energy efficiency values which can create risks.

5.8 As insulation improves and is made thicker (to improve the u-value of a wall), moisture vapour builds up inside a wall and the temperature conditions are altered and the vapour can turn to water, this is known as Interstitial Condensation.

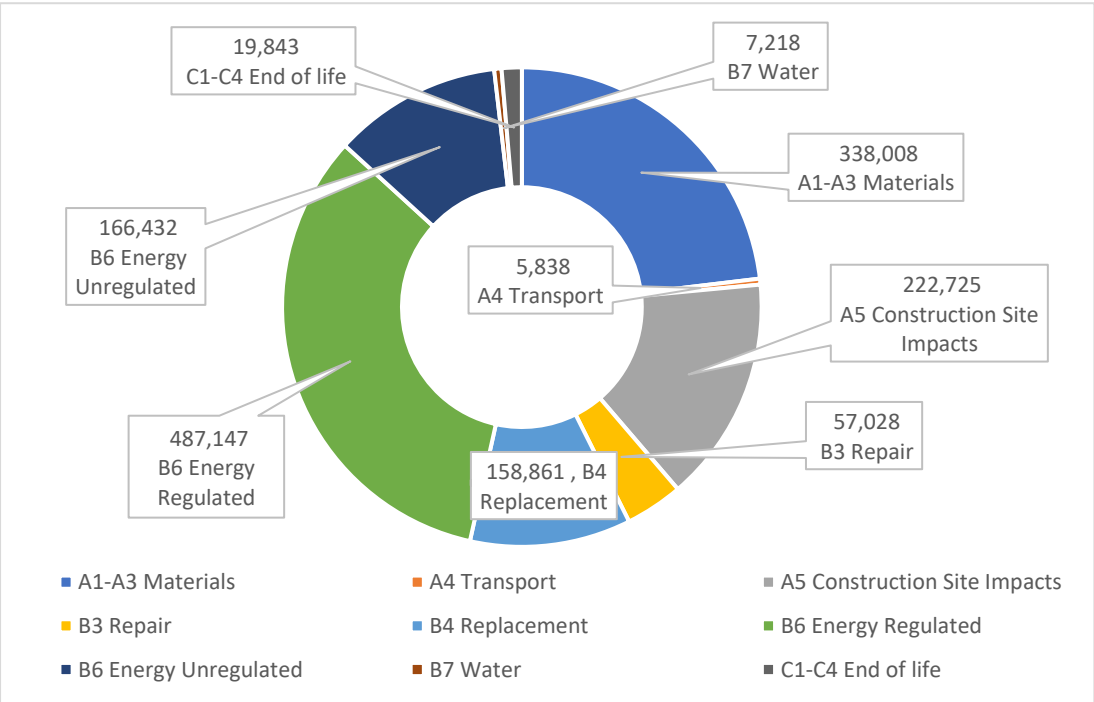

Figure 7: Option 2 - total kgCO_2 / 60 years – Life cycle emissions

Option Three

5.9 This option involves the retention of the valuable front façade and sides whilst deconstructing and reconstructing the rest of the house whilst using materials from the existing building. It includes a significant improvement to wall u-values, thermal bridging values and an overall improvement to the building fabric. A significant extension of the basement is also included in this option.

5.10 The rebuilding of the building envelope behind the retained façade and sides at the Proposed Development allows for significant improvements in the following:

> **Improved envelope performance** – Greater U-values and lower heat loss.

> **Improved airtightness** – Less heat lost through ventilation.

> **Improved thermal bridging** – Less heat lost through construction joints.

5.11 The above factors significantly contribute to the reduction in energy demand during use (Module B6). The retention of the front façade and sides does cause a very slight reduction in performance however its heritage value outweighs the sustainability gain. The significant reuse of materials allows for the reduction of emissions in A1-A3 emissions (materials). Whilst the use of cement replacement products allows for a lower carbon concrete with 60% CO_2 reduction in comparison to standard CEM I concrete.

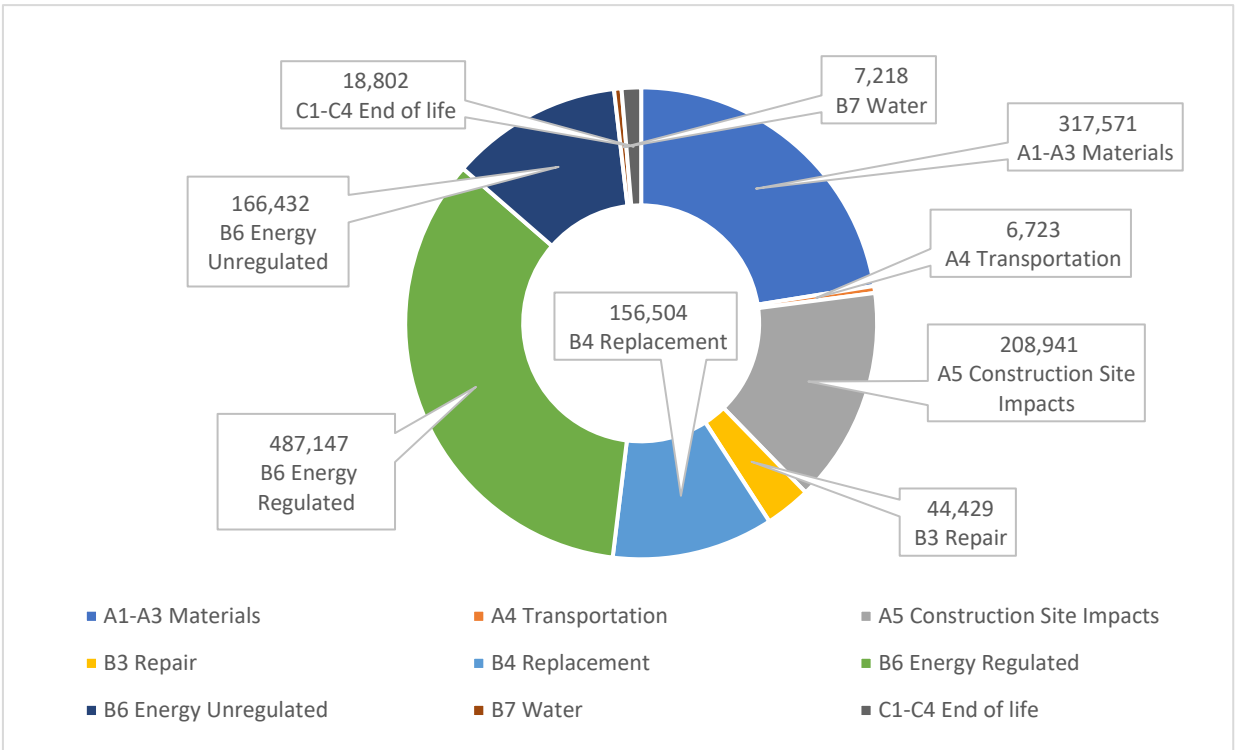

Figure 8: Option 3 - total $kgCO_2$ / 60 years – Life cycle emissions

5.12 The above figures demonstrate the total $kgCO_2$ over 60 years per Option. Table 3 below take these figures and expresses them as a percentage against each life cycle module.

Table 3: Total $kgCO_2$ / 60 years percentage share – Life cycle emissions

Life cycle module	Option 1	Option 2	Option 3
A1-A3 Materials	3.59%	23.10%	22.46%
A4 Transportation	0.04%	0.40%	0.48%
A5 Construction Site Impacts	3.36%	15.52%	14.78%
B3 Repair	0%	3.90%	3.14%
B4 Replacement	0%	10.86%	11.07%
B6 Energy Regulated	87.33%	33.30%	34.46%
B6 Energy Unregulated	5.39%	11.38%	11.77%
B7 Water	0.23%	0.49%	0.51%
C1-C4 End of life	0.05%	1.36%	1.33%

6. CIRCULAR ECONOMY

6.1 A circular economy is defined in the London Plan Policy *SI7 'Reducing Waste and Supporting the Circular Economy'* as one where materials are retained in use at their highest value for as long as possible and are then reused or recycled, leaving a minimum of residual waste.

6.2 In contrast to a linear economy (take, make, dispose), a circular economy keeps products and materials circulating through the system at their highest value for as long as possible, through re-use, recycling, refurbishment, and remanufacturing.

6.3 The end goal is to retain the value of materials and resources indefinitely, with no residual waste at all. This is possible but will require a fundamental change in the way that buildings are designed, built, operated, and deconstructed.

6.4 Applying circular economy thinking to the built environment is complex, with many overlapping issues and trade-offs to consider. However, there are some core guiding principles that promote a

regenerative and restorative whole systems approach that should be applied on every project. These are as follows:

1. **Conserve resources and source ethically.**

> Minimise the quantities of materials used

> Minimise the quantities of other resources used

> Specify and source materials and other resources responsibly and sustainably

2. **Design to eliminate waste (and for ease of maintenance).**

> Design for longevity, adaptability or flexibility and reusability or recoverability

> Design out construction, demolition, excavation, and municipal waste arising

3. **Manage waste sustainably and at the highest value.**

> Manage demolition waste

> Manage excavation waste

> Manage construction waste

> Manage municipal waste

6.5 The three Options presented in this report all support Circular Economy Principles in one way or another. As outlined above, Option One is the most favourable in terms in $kgCO_2$ over a 60-year period. This Option has considered Circular Economy principles in the following ways.

Minimised Material Use

6.6 The design team have adopted a design approach that focuses on material resource efficiency so that less material is used in the design (e.g., lean design), and / or less waste is produced in the construction process, without compromising the design concept.

6.7 It is proposed that the material removed in the reconstruction of the home (bricks, timber and roof tiles) are being re-used in the reconstruction of the proposed development. This ensures that the number of new materials required is reduced and less waste is being removed from the site. All waste generated during the removal will be re-used wherever possible.

6.8 Each existing Mechanical and Electrical material/product in the existing development will be evaluated for possible salvage/reuse. Reuse will have priority over salvage; an economic, viability and safety assessment will be made for each item/material.

6.9 Use of a lower carbon concrete that allows for a 60% CO_2 reduction when compared to standard CEM I concrete.

6.10 Based on the above, the materials for the proposed development will look to exceed the GLA benchmark of 20% reused or recycled content across all materials.

Designing for Longevity

6.11 The proposed development is designing with longevity in mind. Examples include protecting materials from degradation due to environmental conditions, adopting passive design strategies to provide resilience, and sizing systems to cope with future climate scenarios.

6.12 Durable, hard-wearing, and low-maintenance façade and roof materials are also proposed. The material palette is predominantly brick, taking inspiration from a local context.

6.13 Products and materials for Mechanical and Electrical services shall be selected on the basis of long-term reliability and low energy usage over initial cost. The ease and speed of building/installing assorted products/systems shall also be compared to reduce operational emissions.

Site Waste Management

6.14 As part of their commitment to divert construction waste from landfill, Size Group (Principal Contractor) will be required to regularly monitor and record the site's waste reduction performance. This will be compared against a target benchmark where at least 95% (by volume) of non-hazardous construction and demolition waste is to be reused or recycled. A benchmark of 95% for potential excavation waste put to beneficial use will also be set.

6.15 Size Group will be required to investigate opportunities to minimise and reduce waste generation, such as:

> Attention to material quantity requirements to avoid over-ordering and generation of waste materials.

> Agreements with material suppliers to reduce the amount of packaging or to participate in a packaging take-back scheme.

> Implementation of a 'just-in-time' material delivery system to avoid materials being stockpiled, which increases the risk of their damage and disposal as waste.

> Segregation of waste at source where practical; and re-use and recycling of materials off-site where re-use on-site is not practical (e.g., through use of an off-site waste segregation facility and re-sale for direct re-use or re-processing.

Sustainable Resourcing

6.16 The development has also taken steps to ensure other resource use will be kept to a minimum. Examples include:

> The development will achieve a total reduction in regulated CO_2 emissions of 71% over the Building Regulations baseline through be lean, be clean and be green on-site measures and will provide homes that are energy efficient and incorporate Low and Zero Carbon technologies.

> All new dwellings will target a minimum internal water efficiency standard of 105 litres/person/day in accordance with the recently adopted London Plan Policy SI5 and the optional tighter Building Regulations Approved Document G requirement (110 litres/person/day).

> The proposed rainwater recycling drainage system will provide recycled rainwater for irrigation supplies. This will reduce the reliance on treated mains water.

> Built on land that is already developed which prevents the development of virgin land.

7. CONCLUSION

7.1 This Whole Life Cycle Carbon Emissions (WLCCE) Assessment has been prepared by Hodkinson Consultancy, a specialist energy and environmental consultancy for planning and development for the proposed development at 14 Greenaway Gardens.

7.2 To support Camden Council in fully understanding the impacts of this proposed development, this report has identified the carbon that will be emitted from the following options:

> **Option 1:** Basement extension only.

> > This option involves the retention of the existing house in its current state with no retrofitting, and a new regulations-compliant basement constructed underneath.

> **Option 2:** Internal retrofit

> > This option looks at the retention and repointing of all existing external walls, the addition of high performing internal insulative lining, and the creation of a new roof and compliant basement.

> > The treatment of the existing walls consists of repointing the existing brickwork, the addition of a 40mm of mineral wool between battens, 100mm of PIR insulation, and 12mm of plasterboard. The same energy strategy for Option 2 has also been applied to Option 3, which includes low u-values and a ground source heat pump.

- **Option 3:** Internal retrofit and partial reconstruction.
    - This option involves a combined approach whereby some existing external walls are retained, and some are rebuilt in a more energy efficient build up. The external walls chosen for retention are those deemed to be a positive contributor to the conservation area. Much of the areas of wall to be rebuilt have already undergone alterations over the past decades. The retention of the south and east elevations and front portions of the west and north façade allow for 89.2% of the original external wall that is visible from the public realm to be preserved.
    - The build-up for the proposed rebuilt walls involves a 215mm brick wall constructed from reclaimed bricks, a cavity break, vapour barrier, 190mm of rockwool insulation between studs, 9mm of OSB and 12mm of plasterboard. Option 3 will ensure that as much material as possible will be reclaimed and reused from the deconstructed elements, including brickwork, roof tiles and timber.
    - The same energy strategy for Option 3 has also been applied to Option 2, which includes low u-values and a ground source heat pump.

7.3 The total $kgCO_2$ demonstrate that the lowest emissions are emitted from Option 3 (internal retrofit and partial reconstruction), this option emits the least emissions over a 60-year period.

7.4 The design principles adopted in the design of Option 3 support a Circular Economy through reduced material use, building material re-use and effective site management techniques.

CALCULATIONS FOR ASSESSMENT

Option 1

Result category	Biogenic carbon (kg CO2e)	A1-A3 Product Stage	A4 Transport	A5 Site operations	B6 Operational Energy use - Regulated	B6 Operational Energy use - Unregulated	B7 Operational Water use	C1-C4 End of Life stage	TOTAL kg CO2e	D External impacts
1 Substructure	-	110,672.77	1,378.53	5,684.44				1,637.52	119,373.27	(53,562.60)
2.1 Frame										
2.2 Upper Floors										
2.3 Roof										
2.4 Stairs & Ramps										
2.5 Ext. Walls										
2.6 Windows & Ext. Doors										
2.7. Int. Walls & Partitions										
2.8 Int. Doors										
3 Finishes										
4 Fittings, furnishings & equipments										
5 Services (MEP)					2,695,637.58	166,431.90	7,218.00		2,869,287.48	
6 Prefabricated										
7 Existing bldg										
8 Ext. works										
Unclassified / Other				98,000.00					98,000.00	
TOTAL kg CO2e kg CO2e	-	110,672.77	1,378.53	103,684.44	2,695,637.58	166,431.90	7,218.00	1,637.52	3,086,660.75	(53,562.60)

Option 2

Result category	Biogenic carbon (kg CO2e)	A1-A3 Product Stage	A4 Transport	A5 Site operations	B3 Repair	B4 Material replacement	B5 Material refurbishment	B6 Operational Energy use - Regulated	B6 Operational Energy use - Unregulated	B7 Operational Water use	C1-C4 End of Life stage	TOTAL kg CO2e	D External impacts
0.3 Supports				47646.51								47646.51	-2518.53
1 Substructure	0	110672.77	1378.53	5684.44	0						1637.52	119373.27	-53562.6
2.1 Frame	-25320	6256.43	445.19	1031.91	0						27235.96	9649.49	-11772.1
2.2 Upper Floors	-33731.28	23468.05	1635.7	3640.52	0	849.01	0				38979.21	34841.21	-21595.4
2.3 Roof	-12293	9682.85	117.55	1455.13	0	10185.24	0				15021.86	24169.63	-9802.88
2.4 Stairs & Ramps			7.55		0						49.52	57.07	-297.29
2.5 Ext. Walls	-4683.64	43653.67	950.54	3408	9591.58	2668.75	0				6911.96	62500.87	-10699.42
2.6 Windows & Ext. Doors	-14279.87	31148.79	122.44	0	29908.1	31148.79	0				14587.12	92635.37	-804.14
2.7. Int. Walls & Partitions	-3363.36	17020.2	53.58	1294.02	0	1075.08	0				4124.88	20204.38	-2726.21
2.8 Int. Doors	-4528.33	2607.79	12.3	0	1758.08	2607.79	0				4838.38	7296.01	-4839.6
3 Finishes	-13287.09	18420.76	68.44	2506.45	7586.09	31024.54	0				14865.12	61184.32	-8391.99
4 Fittings, furnishings & equipments	-5975.93	14808.96	89.5	907.02	5540.97	25249.12	0				7139.55	47759.18	-28165.23
5 Services (MEP)	0	43747.4	94.01	425.5	2643.66	54052.82	0	487147.08	166431.9	7218	1581.69	763342.06	-34948.74
6 Prefabricated													
7 Existing bldg													
8 Ext. works	-15430.5	2187.85	37.26	107.28	0						15474.76	2376.65	-217.13
Unclassified / Other	0	14332.06	825.2	154617.84	0						288.74	170063.83	-2891.5
TOTAL kg CO2e	-132893	338007.58	5837.8	222724.62	57028.48	158861.13	0	487147.08	166431.9	7218	152736.26	1463099.9	-193232.8

Option 3

Result category	Biogenic carbon (kg CO2e)	A1-A3 Product Stage	A4 Transport	A5 Site operations	B3 Repair	B4 Material replacement	B6 Operational Energy use - Regulated	B6 Operational Energy use - Unregulated	B7 Operational Water use	C1-C4 End of Life stage	TOTAL kg CO2e	D External impacts
0.3 Supports				50776.98							50776.98	-1728.28
1 Substructure		110672.8	1378.53	5684.44						1637.52	119373.3	-53562.6
2.1 Frame		11067.28	137.85	568.44						163.75	11937.33	-5356.26
2.2 Upper Floors	-33731.28	64230.83	1635.7	5791.52		849.01				38979.21	77754.99	-21821.18
2.3 Roof	-12293	9682.85	117.55	1455.13		10185.24				15021.86	24169.63	-9802.88
2.4 Stairs & Ramps			7.55							49.52	57.07	-297.29
2.5 Ext. Walls		436.75	2700	-209.63		573.94				3209.3	6710.35	-17330.12
2.6 Windows & Ext. Doors	-14279.87	31148.79	122.44		18947.09	31148.79				14587.12	81674.36	-804.14
2.7. Int. Walls & Partitions	-3363.36	5110.73	42.84	715.12		1075.08				4117.92	7698.32	-2163.79
2.8 Int. Doors	-4528.33	2607.79	12.3		1758.08	2607.79				4838.38	7296.01	-4839.6
3 Finishes	-13287.09	18420.76	68.44	2506.45	7586.09	31024.54				14865.12	61184.32	-8391.99
4 Fittings, furnishings & equip	-5975.93	14808.96	89.5	907.02	5540.97	25249.12				7139.55	47759.18	-28165.23
5 Services (MEP)		47195.9	98.04	638.54	10596.81	53790.29	487147.08	166431.9	7218	1510.85	774627.4	-41288.28
6 Prefabricated												
7 Existing bldg												
8 Ext. works	-15430.5	2187.85	37.26	107.28						15474.76	2376.65	-217.13
Unclassified / Other			275.07	140000						96.25	140371.3	-926.76
TOTAL kg CO2e	-102889.4	317571.3	6723.07	208941.3	44429.03	156503.79	487147.08	166431.9	7218	121691.1	1413767	-196695.53

Energy calculations

Provided by ME7 in the Energy and Sustainability Statement (April 2022).

Proposed Option	Regulated kWh/annum	Unregulated kWh/annum
Option 1 - Basement extension only	192,821	11,905
Option 2 – Internal retrofit	34,846	11,905
Option 3 – Internal retrofit and partial reconstruction	34,846	11,905