CUNDALL

9D The Grove, Highgate, London

Whole Life Carbon Assessment Statement
London Borough of Camden Council

Job No:	1035879
Doc Ref:	-9DG-CDL-XX-XX-RP-SY-70204
Revision:	P01
Revision Date:	15 December 2022

Project title	9D The Grove, Highgate, London	Job Number
Report title	Whole Life Carbon Assessment Statement	1035879

Document Revision History

Revision Ref	Issue Date	Purpose of issue / description of revision
P01	15 December 2022	Issued for comment.

Document Validation (latest issue)

15/12/2022
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Executive Summary

The following Whole Life Carbon Assessment has been prepared to compare development scenarios for 9D The Grove, where three options were analysed:

- Option 1 - Retrofit for the existing dwelling
- Option 2 - Replacement dwelling
- Option 3 - Extension and retrofit of the existing dwelling

The comparative early design stage WLC assessment was carried out using the following information:

- Design information at the given time, as supplied by the design team.
- Default material baseline, as recommended by the RICS Professional Statement (PS).
- Component life spans, as recommended by RICS PS.

This established a carbon standing for different design options. The main objectives being:

- To assess the whole life carbon footprint positions of the three options.
- To integrate low carbon thinking into the project design and construction.

For this exercise, the Sturgis Carbon calculator was used to calculate the Whole Life Carbon emissions results. The assessment tool is verified by the BRE and GLA to carry out Whole Life Carbon assessment.

Whole life-cycle material carbon summary

The assessment was carried out according to the British Standard BS EN15978:2011 (Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method), and the RICS Professional Statement 'Whole life carbon assessment for the built environment 2017'.

The total Whole Life-cycle material carbon emissions (including operational emissions) of the Option 1 - Retrofit for the existing dwelling amount to 139 tonnes CO_2e, with 55 tonnes associated with the initial construction and 84 tonnes over the life cycle of the buildings.

The total Whole Life-cycle material carbon emissions (including operational emissions) of the Option 2 - Replacement dwelling amount to 417 tonnes CO_2e, with 240 tonnes associated with the initial construction and ~177 tonnes over the life cycle of the buildings.

The total Whole Life-cycle material carbon emissions (including operational emissions) of the Option 3 - Extension and retrofit of the existing amount to 454 tonnes CO_2e, with 217 tonnes associated with the initial construction and 237 tonnes over the life cycle of the buildings.

Module D has also been reported but not included in the total figures. This breakdown for the development is summarised in Table 1.

Tonne CO_2e	Option 1 Retrofit of Existing Building	Option 2 Replacement	Option 3 Extension & retrofit
Carbon at completion excl. sequestration (Module A1-A5)	55	240	217
Carbon Over life cycle (Module B to C exc. B6, B7)	42	134	139
Carbon from energy use (B6)	42	43	98
Total Carbon Tonne CO_2e	**139**	**417**	**454**
Module D (excluded from total figures)	-3	-5	-5

Table 1: Whole Life-cycle material carbon emissions breakdown (Tonne CO_2e)

Kg CO_2e/m^2 GIA	Option 1 Retrofit of Existing Building	Option 2 Replacement	Option 3 Extension & retrofit
Carbon at completion excl. sequestration (Module A1-A5)	317	590	544
Carbon Over life cycle (Module B to C exc. B6, B7)	244	330	346
Carbon from energy use (B6)	243	107	246
Total Carbon $KgCO_2e/m^2$	804	1,026	1,136
Module D (excluded from total figures)	-19	-13	-13

Table 2: Whole Life-cycle material carbon emissions breakdown (Kg CO_2e/m^2 GIA)

The operational carbon emissions including the operational energy use corresponding with life-cycle module B6 for Option 1 - Retrofit of the existing dwelling and Option 2 - Replacement dwelling are estimated to amount to 42 tonnes CO_2e and 43 tonnes CO_2e over the 60-year life cycle of the development, respectively. Values are based upon indicative consumptions provided in the 'Energy statement' prepared Iceni Projects Limited, assuming a highly efficient air source heat pump (ASHP) system under the replacement scenario and an air source heat pump (ASHP) system with typical manufacturer specifications under the retrofitted and/or extension scenarios will be employed.

The operational carbon emissions for the Option 3 - Extension and retrofit of the existing are estimated to amount to 98 tonnes CO2e over the 60-year life cycle of the development. This is significantly higher than the other two scenarios. Even though the combined option with the extension and the retrofit assumes the same systems as those prescribed for the retrofit scenario, the increase in area as compared to the 'retrofit only' option could be the reason for higher emissions. In addition, the heat loss through the retained building fabric when compared to new elements with lower U-values may be a contributor to higher energy consumption.

The operational water use, corresponding to module B7 are not included in this assessment.

Low carbon design development

The following options have been incorporated into the design to reduce the carbon footprint of the proposed options:

- Local sourced (UK) heavy material like brick and blockwork.
- Local sourcing of concrete – within 10-25km.
- High cement replacement GGBS (Ground Granulated Blast-furnace Slag) or PFA (Pulverised Fuel Ash) for concrete used in both substructure and superstructure.
- Timber framed glazing.
- Investigation of BDA low carbon brickwork for external walls.
- Internal finishes such as tiles (both porcelain and vinyl) and carpet to contain high recycled content.
- Low carbon paint for wall finishes.

Comparison with GLA benchmarks

In order to understand the performance of the proposed development, the results have been compared with the Greater London Authority (GLA) benchmark emission rate for residences. It must be noted that the GLA benchmarking is for demonstration purposes as this development proposal is of a much smaller scale.

The results show that all the options for the 9D The Grove development currently meet and better both the upfront and life-cycle embodied carbon performance benchmarks set by the GLA. See 2.5.7 for full details on these.

The benchmarks include all life-cycle modules apart from B6, B7 (operational energy and operational water) and module D.

Conclusions

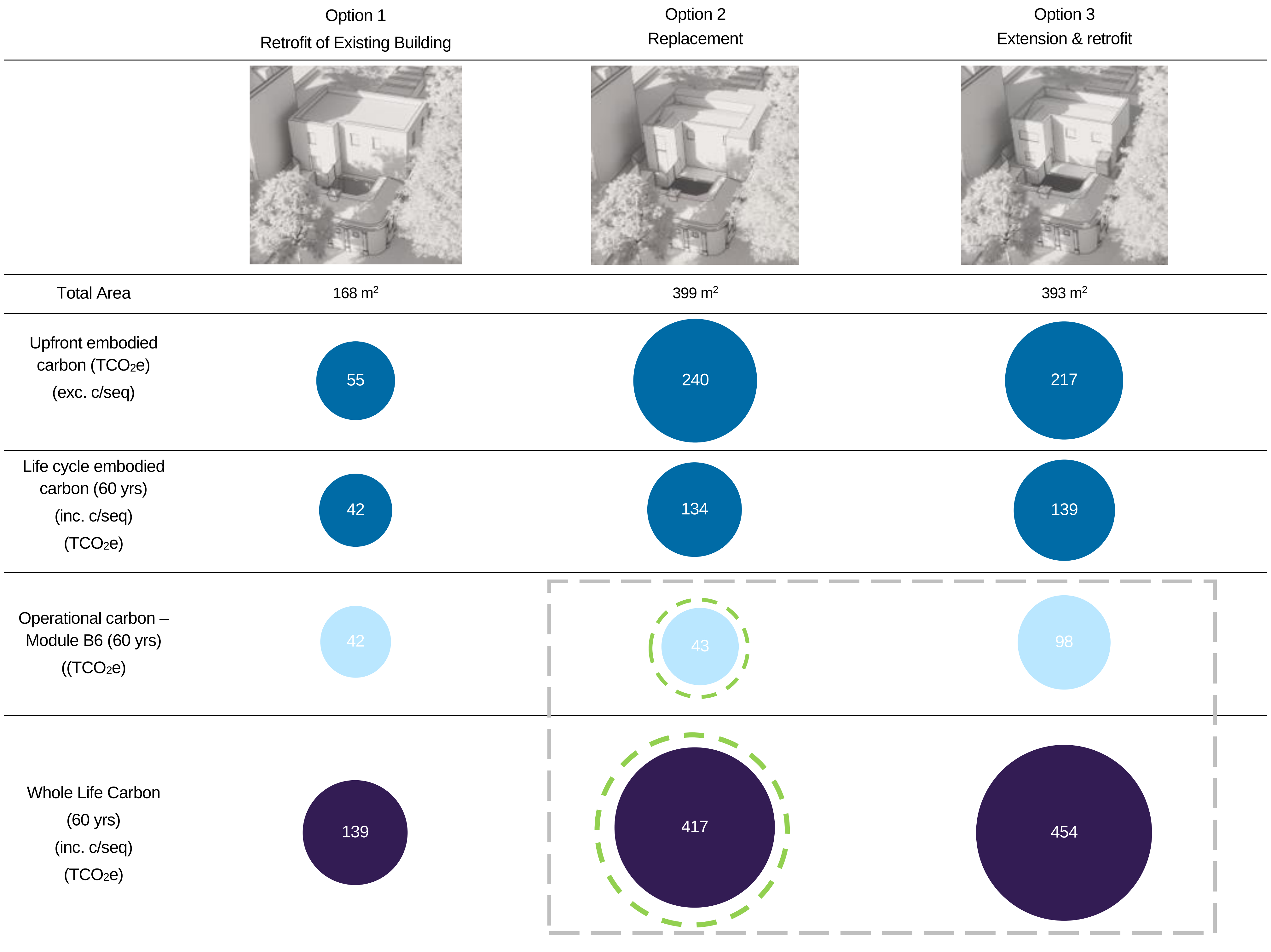
Overall, the replacement dwelling showed the highest upfront embodied carbon emissions compared to its refurbished and/or extended counterparts. This is because the refurbished options retain the existing structure. However, the greatest impact of the replacement dwelling is on the operational carbon reductions, accounting for 107 $kgCO_2e/m^2$ in comparison to the 243 $kgCO_2e/m^2$ for the refurbished scenario and 246 $kgCO_2e/m^2$ for the extended and refurbished scenario. The overall impact of this can be seen on the Whole Life Carbon ($kgCO_2e$) impact, which is noticeably lower for the new replacement dwelling in comparison to its closest counterpart, the retrofitted and extended option.

The comparison of results for all three options over a 60-year lifecycle is summarised in Figure 1 and 2 and Table 3. For like-to-like comparison in terms of area, the comparison between the replacement dwelling, and the extension and retrofit of the existing dwelling demonstrates that the carbon gap between them shifts after 23 years, whereby the new replacement dwelling continues to outperform the retrofitted and extended dwelling over the lifecycle. This results in a significant carbon gap at the end of lifecycle between the two options.

Hence, despite the retrofitted dwelling alone and the retrofitted dwelling with the new extension, both demonstrating lower upfront embodied carbon emissions, the higher operational carbon emissions would more than outweigh this over the life cycle and, therefore, offer best carbon payback with the new replacement dwelling.

Total Whole Life-Cycle Carbon		Tonnes CO_2e	$kgCO_2e/m_2$ GIA
Option 1 **Retrofit of Existing Building**	Upfront Embodied Carbon (A1-A5)	55	317
	Whole Life Carbon (A-C)	139	804
Option 2 **Demolition & New Replacement**	Upfront Embodied Carbon (A1-A5)	240	590
	Whole Life Carbon (A-C)	417	1,026
Option 3 **Extension & Retrofit**	Upfront Embodied Carbon (A1-A5)	217	544
	Whole Life Carbon (A-C)	454	1,136

Table 3: Whole life carbon comparison showing 9D The Grove's Retrofit of existing dwelling, Replacement dwelling and Extension and retrofit of existing dwelling.



Whilst retrofitting demonstrated the lowest upfront embodied carbon emissions per m^2 of GIA, it features the highest operational carbon emissions among all three options. This may be attributed to the heat loss through the retained building fabric as compared to new elements.

The replacement dwelling showed highest upfront embodied carbon emissions compared to its refurbished and extended counterparts, however the greatest impact was seen on the operational carbon reductions. Consequently, its overall Whole life carbon is >40 TCO_2e lower as compared to its closest counterpart, the 'Retrofit & Extension' scenario.

The extension and retrofit of the existing dwelling resulted in slightly lower upfront embodied carbon among the two comparable options. However, its operational carbon emissions significantly outweigh its comparable counterpart. This may be due to the typical system specifications in the retrofitted & extended dwelling as opposed to a highly efficient system utilised for the replacement option, in addition to the heat loss through the retained building fabric as compared to new elements.

Figure 1: Comparison of the Whole Life-cycle carbon emissions

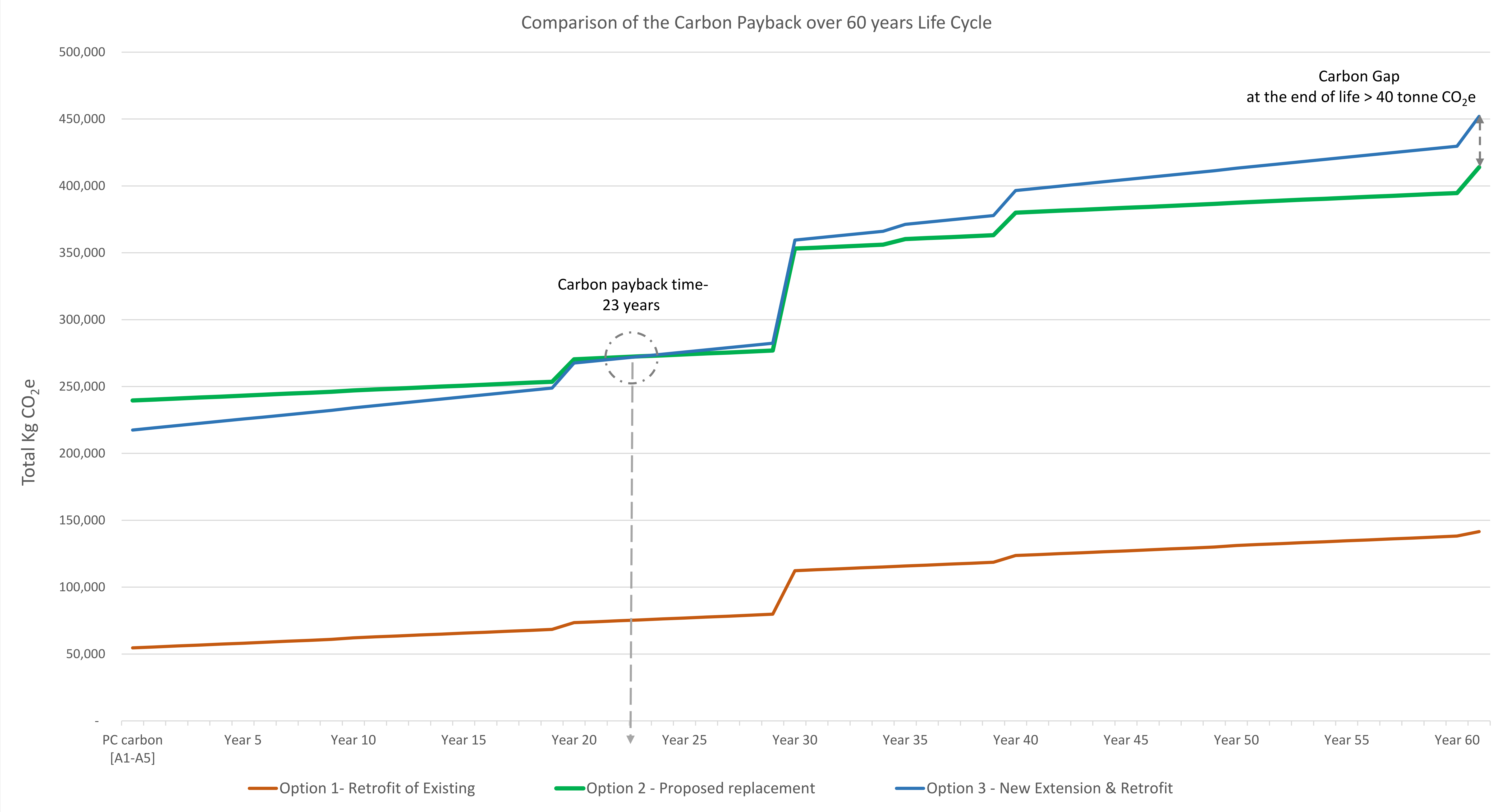


Figure 2: Comparison of the aggregated carbon emissions over 60 years Life Cycle

Contents

1.0

Introduction

Introduction

1.1 Purpose of Statement

This statement is submitted as part of a planning application for the redevelopment of the existing 9D The Grove Building.

Primarily, the statement seeks to assess the current carbon footprint position for three development scenarios:

- Option 1 - Retrofit for the existing dwelling
- Option 2 - Replacement dwelling
- Option 3 - Extension and retrofit of the existing dwelling

The assessment was carried out in accordance with the British Standard BS EN15978:2011 (Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method), and the RICS Professional Statement 'Whole life carbon assessment for the built environment 2017'.

1.2 Project Description

9D The Grove is situated within the Highgate ward of the London Borough of Camden and was originally constructed in the post-war era of the 1950s.[1] The site is bound by The Grove to the east, and Fitzroy Park to the north. The surrounding area is dominated by residential uses in all directions, with residences typically being detached in nature, and up to four-storeys in height.

The site is currently occupied by a detached ground plus two-storey residential dwelling. The proposal seeks to replace the existing dwelling on-site with a new family dwelling of high-quality design and sustainability credentials that will serve to enhance the character and appearance of the surrounding area.

This document details the whole life carbon assessment undertaken to compare both the embodied and whole life carbon emissions associated with three development scenarios for this development: Option 1 - Retrofit to the existing dwelling at 9D The Grove, Option 2 - Demolition and replacement of the existing dwelling, and Option 3 - New extension and retrofit to the existing dwelling.

1.3 Aims of the Assessment

This assessment aims to allow a comparative early design stage WLC assessment for these scenarios over the lifetime of the development.

Whole life-cycle carbon emissions are the total greenhouse gas emissions arising from a development over its lifetime, from the emissions associated with raw material extraction, the manufacture and transport of building materials, to installation/construction, operation, maintenance, and eventual material disposal.

They capture a building's operational carbon emissions from both regulated and unregulated energy use, as well as its embodied carbon emissions. This includes emissions 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.

A WLC assessment also includes an assessment of the potential carbon emissions 'benefits' from the reuse or recycling of components after the end of a building's useful life. It provides a true picture of a building's carbon impact on the environment.

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 and eventual material disposal.

Calculating and reducing WLC emissions offers a wealth of benefits including:

- Ensuring that a significant source of emissions from the built environment are accounted for, which is necessary in achieving a net zero-carbon city.
- Achieving resource efficiency and cost savings by encouraging the re-use of existing materials instead of new materials and the retrofit and retention of existing structures and fabric over new construction.
- Identifying the carbon benefits of using recycled material and the benefits of designing for future reuse and recycling to reduce waste and support the circular economy.
- Encouraging a 'fabric first' approach to building design thereby minimising mechanical plant and services in favour of natural ventilation.
- Considering operational and embodied emissions simultaneously to find the optimum solutions for the development over its lifetime.
- Identifying the impact of maintenance, repair and replacement over a building's life cycle which improves life-time resource efficiency and reduces life-cycle costs, contributing to the future proofing of asset value.
- Encouraging local sourcing of materials and short supply chains, with resulting carbon, social and economic benefits for the local economy.
- Encouraging durable construction and flexible design, both of which contribute to greater longevity, reduced obsolescence of buildings and avoiding carbon emissions associated with demolition and new construction.

1.4 Methodology

The assessment followed RICS and GLA's Whole Life-Cycle Carbon Assessments guidance and a nationally recognised assessment methodology, namely, BS EN 15978: 2011: (Sustainability of construction works — Assessment of environmental performance of buildings — Calculation method).

Underpinning BS EN 15978 is the RICS Professional Statement: Whole Life Carbon assessment for the built environment (referred to as the RICS PS for the remainder of this document). The RICS PS serves as a guide to the practical implementation of the BS EN 15978 principles. It sets out technical details and calculation details and was used as the methodology for the assessment.

The assessment should cover the development's carbon emissions over its lifetime, accounting for:

- its operational carbon emissions (both regulated and unregulated)
- its embodied carbon emissions

The operational water use, corresponding to Module B7 are not included in this assessment.

1.5 Life-cycle modules

BS EN 15978 and RICS PC have set out the stages within a typical project's lifetime, known as the life-cycle modules.

The WLC assessment covers the all-modules A, B and C set out in BS EN 15978 and the RICS PS in the life of a typical project described as life-cycle modules. The reference study period (i.e., the assumed building life expectancy) for the purposes of the assessment is 60 years.

To provide a holistic view of the Global Warming Potential (GWP), the whole life carbon assessment accounts for all components relating to the project during all life stages. Embodied carbon emissions are attributed to the following main categories taken from BS EN 15978. The categories are:

- Product Stages (module A1 to A3): The carbon emissions generated at this stage arise from extracting the raw materials from the ground, their transport to a point of manufacture and then the primary energy used (and the associated carbon impacts that arise) from transforming the raw materials into construction products.
- Construction (module A4 to A5): These carbon impacts arise from transporting the construction products to site, and their subsequent processing and assembly into the building.
- In-Use Stages (module B1 to B5): This covers a wide range of sources from the embodied carbon emissions associated with the operation of the building, including the materials used during maintenance, replacement, and refurbishment.
- End of Life Stages (module C1 to C4): The eventual deconstruction and disposal of the existing building at the end of its life takes account of the on-site activities of the demolition contractors. No 'credit' is taken for any future carbon benefit associated with the reuse or recycling of a material into new products.

[1] Energy & Sustainability Assessment. September 2021 - Rev 00. Charlton Brown Architecture & Interiors

Please note that demolition has been included in this assessment.

1.6 Benchmarking

The Greater London Authority (GLA) has benchmarks for certain building types including Residential buildings. These, published in March 2022, will be used, which represents typical Residential schemes.

The WLC benchmarks include all life-cycle modules apart from B6, B7 (operational energy and operational water) and module D. It must be noted that the GLA benchmarking is an indicative demonstration as this development proposal is of a much smaller scale. Comparison against benchmarks and other assessments provides an initial indication of the performance of the proposed project development against current industry average.

The benchmark values, as taken from the GLA's Whole Life-Cycle Carbon Assessments London Plan guidance, are displayed in Table 1-2.

Stage	GLA Benchmark (kg CO_2e/m^2 GIA)	GLA Aspirational Benchmark (kg CO_2e/m^2 GIA)
Carbon at completion (A1-A5)	<850	<500
Carbon Over life cycle (B-C exc. B6 & B7)	<350	<300

Table 1-1: GLA WLC benchmarks for Residential

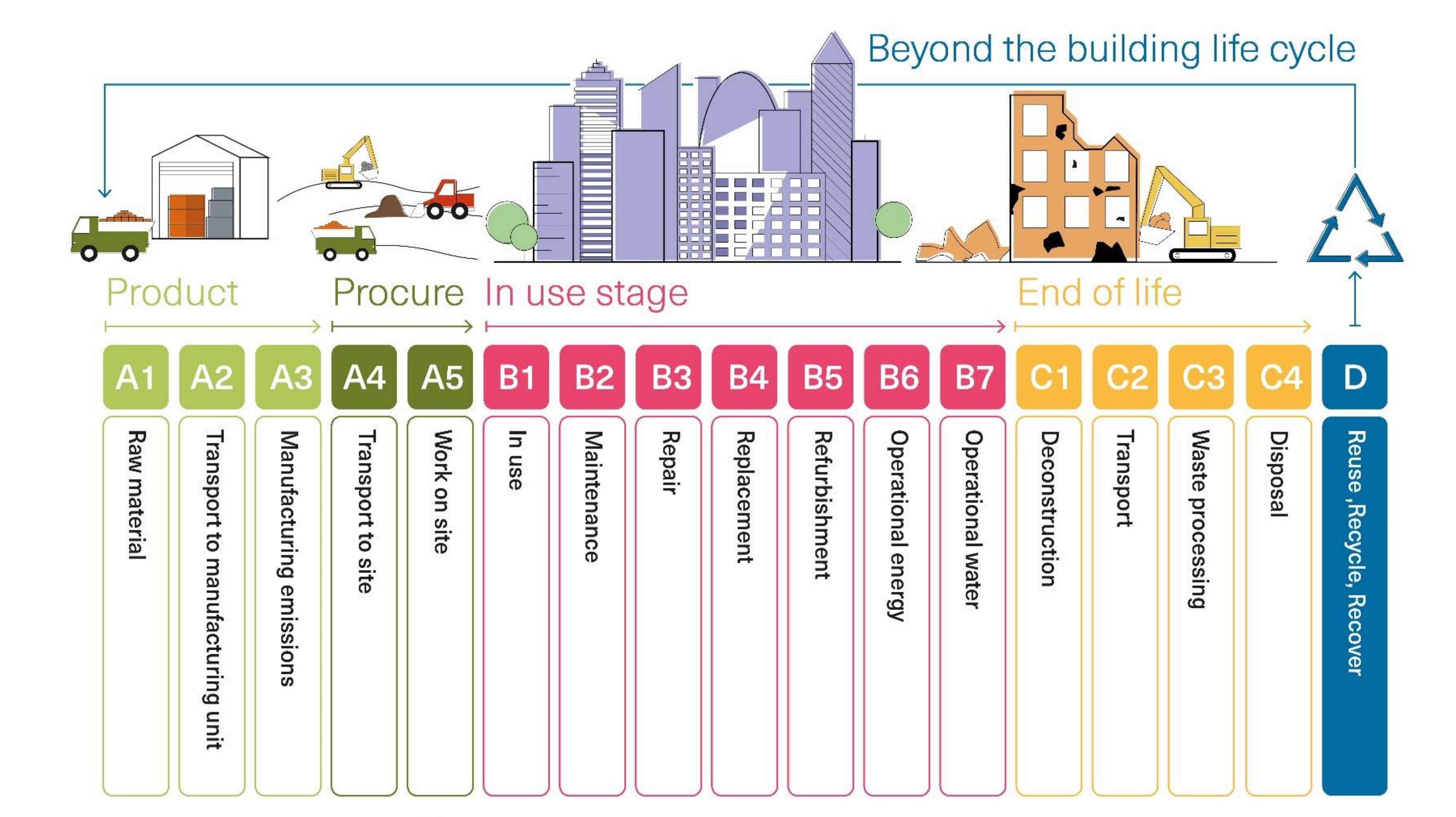


Figure 1-1: Life Cycle Modules as per BS EN 15978

2.0

Whole Life Carbon Assessment

Whole Life Carbon Assessment

2.1 Assessment Process

An early design stage WLC assessment was carried out for all the development scenarios using the following information:

- Design information at the given time, as supplied by the design team.
- Default material baseline, as recommended by the RICS Professional Statement (PS).
- Component life spans, as recommended by RICS PS.

This established a carbon standing for different design options. The main objectives being:

- To assess the current carbon footprint position.
- To integrate embodied carbon thinking into the project design and construction.
- To identify embodied carbon footprint reduction options of the project.

2.2 Data Source and General Assumptions

Design information used:

- Whole Life Carbon Assessment by Iceni Projects Limited on behalf of Charlton Brown Architects Ltd.
- Energy & Sustainability Assessment by Charlton Brown Architecture & Interiors
- Design and Access Statement by Charlton Brown Architecture & Interiors
- Architectural design reports and drawings provided by Charlton Brown Architecture & Interiors
- Brief Specification (November 2022) provided by Charlton Brown Architecture & Interiors.
- Energy statement by Iceni Projects Limited (December 2022) on behalf of Nir Cohen
- Communication and discussion with the design team and the Client

Assessment tool used:

- Sturgis Carbon calculator and its associated material EPD database

The following material specification, transport and life span general assumptions taken from the RICS Professional Statement were used for the WLC initial early design assessment where more project specific information is not currently available:

Material	Details	Specification
Concrete	Piling	C32/40 20% cement replacement
	Substructure	C32/40 20% cement replacement
	Superstructure	C32/40 20% cement replacement
	Generic concrete	C16/20 0% cement replacement
Steel	Reinforcement bars	97% Recycled Content
	Structural steel sections	20% Recycled Content
	Studwork/Support frames	Galvanised steel, 15% Recycled Content
Blockwork	Precast concrete blocks	Lightweight blocks for building envelope
		Dense blocks for other uses
Timber	Manufactured structural timber CLT, Glulam, etc.	100% FSC/PEFC
	Formwork	Plywood
	Studwork/Framing/Flooring	Softwood
Aluminium	Cladding panels	Aluminium sheet, 35% Recycled Content
	Glazing frames	Aluminium sheet, 35% Recycled Content
Plasterboard	Partitioning/Ceilings	Min. 60% Recycled Content
Insulation	To floors, roofs & external walls	PIR

Table 2-1: Default specifications for main building materials

Transport scenario	km by road	km by sea
Locally manufactured e.g. concrete, aggregate, earth	50	-
Nationally manufactured e.g. plasterboard, blockwork, insulation	300	-
European manufactured e.g. CLT, façade modules, carpet	1,500	-
Globally manufactured e.g. specialist stone cladding	200	10,000

Table 2-2: Default transport scenarios for UK projects

Building part	Building elements/components	Expected lifespan
Roof	Roof coverings	30 years
Superstructure	Internal partitioning and dry lining	30 years
Finishes	Wall finishes: Render/Paint	30/10 years respectively
	Floor finishes Raised Access Floor (RAF)/Finish layers	30/10 years respectively
	Ceiling finishes Substrate/Paint	20/10 years respectively
FF&E	Loose furniture and fittings	10 years
Services/MEP	Heat source	20 years
	Space heating and air treatment	20 years
	Ductwork	20 years
	Electrical installations	30 years
	Lighting fittings	15 years
	Communications installations and controls	15 years
	Water and disposal installations	25 years
	Sanitaryware	20 years
	Lift and conveyor installations	20 years
Façade	Opaque modular cladding e.g. rain screens, timber panels	30 years
	Glazed cladding/Curtain walling	35 years
	Windows and external doors	30 years

Table 2-3: Default Life Span assumptions

2.3 Assessment Scenarios

2.3.1 Option 1: Retrofit of the Existing Building

The first scenario calculates the whole life carbon emissions associated with a retrofit option for the existing dwelling. This is a two-storey building with an estimated GIA of 168 m^2. The materials to be employed for the proposed dwelling were extracted from the 'Whole Life Carbon Assessment' carried out by Iceni Projects Limited as well as the 'Brief Specification' provided by Charlton Brown Architecture & Interiors. The main interventions proposed as part of this retrofit option include:

- The existing building would be stripped completely internally
- Ground Floor will have insulation above the existing floor across the total ground floor area
- The existing cavity walls will have insulation into the existing cavity
- Thick polyisocyanurate (PIR) insulation boards across the total roof area.
- The roof covering will be replaced
- The existing single glazed windows to be replaced with double glazed windows and all doors will be replaced
- New steels to support the first floor to enable a new layout to the ground floor

The retrofit scenario assumes the space and heating demand to be served by an air source heat pump (ASHP) system with typical manufacturer specifications. The incorporation of photovoltaic (PV) and/or solar thermal hot water (STHW) panels have also been included. This is assumed as per the 'Energy statement' prepared by Iceni on behalf of the client.

2.3.2 Option 2: Proposed Demotion and New Replacement

The second scenario calculates the whole life carbon emissions associated with the demolition of the existing dwelling on-site, and the construction of the proposed replacement family home. The replacement scheme is a two-storey building with an additional basement floor and an estimated GIA of 399 m^2.

The materials proposed to be employed for the proposed dwelling were extracted from the same 'Whole Life Carbon Assessment' carried out by Iceni Projects Limited as well as the 'Brief Specification' provided by Charlton Brown Architecture & Interiors. This is also supported by information provided within the accompanying Design and Access Statement, prepared by Charlton Brown Architects Ltd.

The proposed replacement scenario assumes the space and heating demand to be served by a highly efficient air source heat pump (ASHP) system, such as the Nilan Compact P. The incorporation of photovoltaic (PV) and/or solar thermal hot water (STHW) panels have also been included. This is assumed as per the 'Energy statement' prepared by Iceni on behalf of the client.

2.3.3 Option 3: New Extension and Retrofit of the Existing Building

The third scenario is a combined scenario that calculates the whole life carbon emissions associated with the retrofit of the existing dwelling with the additional new extension. This is a two-storey building with an additional basement floor and an estimated GIA of 393 m^2. It has been assumed that new building elements would achieve the U-values proposed for the replacement dwelling, and that the retained elements would be improved in line with the retrofit scenario detailed above. Moreover, the combined scenario assumes the same systems as those prescribed for the retrofit scenario in section 2.3.1.

The Energy modelling has been undertaken using the Standard Assessment Procedure (SAP) by Iceni for all the three scenarios above.

2.4 Scope of Assessment

The following building element and category (where applicable) were included in the assessment of the proposal.

Building element group	Building element (NRM level 2)	%
0.Demolition	0.1 Toxic/hazardous/contaminated material treatment	Excluded
	0.2 Major demolition works	95
0.Facilitating works	0.3 & 0.5 Temporary/enabling works	95
	0.4 Specialist groundworks	99
1 Substructure	1.1 Substructure	99
2 Superstructure	2.1 Frame	99
	2.2 Upper floors incl. balconies	100
	2.3 Roof	95
	2.4 Stairs and ramps	100
	2.5 External walls	95
	2.6 Windows and external doors	100
	2.7 Internal walls and partitions	95
	2.8 Internal doors	100
3 Finishes	3.1 Wall finishes	100
	3.2 Floor finishes	100
	3.3 Ceiling finishes	100
4 FF&E	4.1 Fittings, furnishings & equipment incl. building-related*	95
5 Building services/MEP	5.1–5.14 Services incl. building-related*	95
6 Prefabricated Buildings and Units	6.1 Prefabricated buildings and building units	n/a
7 Work to Existing Building	7.1 Minor demolition and alteration works	n/a
8.External works	8.1 Site preparation works	n/a
	8.2 Roads, paths, paving and surfacing	95
	8.3 to 8.8 Fencing, railings, and walls	n/a

Table 2-4: Scope of assessment

* Building-related items: building-integrated technical systems and furniture, fittings and fixtures built into the fabric or included in the shell and core specification. Building-related MEP and FF&E typically include the items classified under Shell and Core and Category A fit-out.

** Non-building-related items: loose furniture, fittings and other technical equipment like desks, chairs, computers, refrigerators, etc. Such items are usually part of Category B fit-out. Therefore, for Shell and Core construction this is not part of the assessment scope.

2.5 Whole Life-Cycle Assessment

2.5.1 Comparative Design Assessment Results

The total Whole Lifecycle carbon emissions (including operational emissions – B6) of the Option 1 - Retrofit for the existing dwelling amount to 139 tonnes CO_2e, with 55 tonnes associated with the initial construction and 84 tonnes over the life cycle of the building*. Similarly, the total Whole Lifecycle carbon emissions (including operational emissions – B6) of the Option 2 - Replacement dwelling amount to 417 tonnes CO_2e, with 240 tonnes associated with the initial construction and 177 tonnes over the life cycle of the building*. Whereas the total Whole Lifecycle carbon emissions (including operational emissions – B6) of the Option 3 - New extension and retrofit of the existing building amount to 454 tonnes CO_2e, with 217 tonnes associated with the initial construction and 237 tonnes over the life cycle of the buildings*. Overall, the whole life carbon emissions for the Option 3 - New extension and retrofit of the existing building are the highest among all three options.

Module D has also been reported for all the options but not included in the total figures.

This breakdown for all the options is summarised is Table 2-5 showing that 39% of the emissions are consumed at practical completion of construction and the other 61% over the life cycle including 30% of operational carbon associated with Module B6 for the retrofitted dwelling. The disproportionately high amount of contribution of operational carbon may be attributed to the use of air source heat pump (ASHP) system with typical manufacturer specifications and a less efficient building fabric.

Whereas, for the new replacement dwelling, 57% of the emissions are consumed at practical completion of construction and the other 43% over the life cycle including 10% of operational carbon. The increased embodied carbon consumed at practical completion of construction are attributed to the new structural elements used, whereas the energy efficient system has led to a lower proportion of the operational energy consumption.

For the extension and retrofit of the existing retrofit, 48% of the emissions are consumed at practical completion of construction and the other 52% over the life cycle including 22% of operational carbon. Again, the comparatively higher amount of contribution of operational carbon may be attributed to the less efficient fabric in the retrofitted areas in addition to the operational emissions associated with the use of typical air source heat pump (ASHP) system as opposed to a highly efficient system.

Tonne CO_2e	Option 1 Retrofit of Existing Building	Option 2 Replacement	Option 3 Extension & retrofit
Carbon at completion excl. sequestration (Module A1-A5)	55	240	217
Carbon Over life cycle* (Module B to C exc. B6, B7)	42	134	139
Carbon from energy (B6)	42	43	98
Total Carbon Tonne CO_2e*	**139**	**417**	**454**
Module D (excluded from total figures)	-3	-5	-5

Table 2-5 Whole life-cycle material carbon emissions breakdown (Tonne CO_2e)

$KgCO_2e/m^2$ GIA	Option 1 Retrofit of Existing Building	Option 2 Replacement	Option 3 Extension & retrofit
Carbon at completion excl. sequestration (Module A1-A5)	317	590	544
Carbon Over life cycle* (Module B to C exc. B6, B7)	244	330	346
Carbon from energy (B6)	243	107	246

Total Carbon $KgCO_2e/m^2$ *	804	1,026	1,136
Module D (excluded from total figures)	-19	-13	-13

Table 2-6: Whole life-cycle material carbon emissions breakdown ($KgCO_2e/m^2$ GIA)

**The whole life cycle carbon emissions and Carbon Over life cycle (B to C module exc. B6, B7) are calculated after including the carbon sequestered by the development. The values for carbon at completion (A1 to A5) do not include sequestration.*

2.5.2 Option 1: Embodied Carbon Breakdown for the Retrofit for the Existing Dwelling

Figure 2-1 shows the embodied carbon breakdown by building element at practical completion of the construction for the potential retrofit for the existing dwelling.

Of the 39% contribution from upfront embodied carbon, the highest values are associated with the Internal walls and finishes.

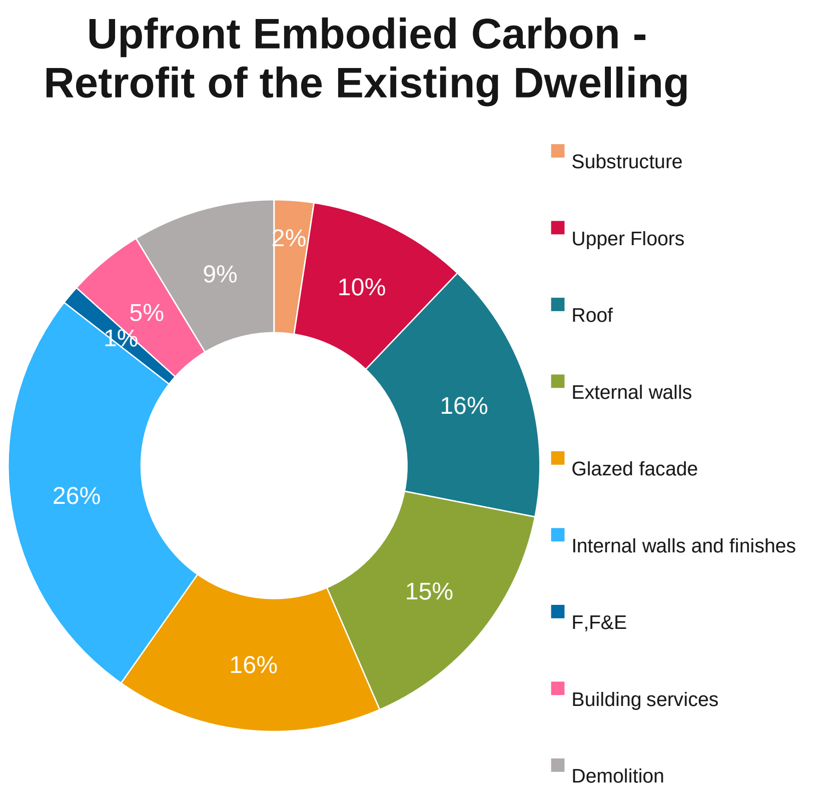


Figure 2-1: Practical completion embodied carbon breakdown of the Retrofitted dwelling.

Table 2-7 gives an elemental breakdown of the aggregated life cycle emissions contributing to the whole life embodied carbon emissions, alongside associated embodied carbon from practical completion for the potential retrofit for the existing dwelling.

Of the 31% contribution from the life cycle embodied carbon, the highest values are associated with the by internal finishes (refurbish & replacement events) followed by glazed facades i.e. the Windows and doors (maintenance, repair, refurbish & replacement events). The embodied carbon of permanently fixed structural items remains constant between practical completion and over the life cycle.

Embodied Carbon over Life Cycle (TCO_2e)		Upfront Carbon (exc. c/seq) [A1-A5]	Life cycle impacts [B2-B5]	End of life impacts [C1-C4]	Whole Life Carbon (inc. c/seq) [A1-C4]
Substructure		1	0	0	1
Superstructure	Frame	0	0	0	0
	Upper Floors	5	0	3	3
	Roof	9	6	0	15
	Stairs and ramps	0	0	0	0
	External walls	8	5	1	14
	Glazed facade	9	7	0	14
Internal walls and Internal finishes		14	19	5	35
F,F&E		1	1	0	2
Building services		3	5	0	8
External Works		0	0	0	0
Demolition		5	0	0	5
Site works		0	0	0	0
Total Embodied Carbon		**55**	**43**	**10**	**97***
Embodied Carbon intensity (kg CO_2e/m^2 GIA)		**317**	**250**	**56**	**561***

Table 2-7: Whole life-cycle embodied carbon emissions of the Retrofitted dwelling.

**The whole life cycle carbon emissions are calculated after including the carbon sequestered by the development. The values for carbon at completion (A1 to A5) and carbon over the lifecycle of the project (B1 to B5 and C1 to C4) do not include sequestration.*

2.5.3 Option 2: Embodied Carbon Breakdown for the New Replacement Dwelling

Figure 2-2 shows the embodied carbon breakdown by building element at practical completion of the construction for the replacement dwelling.

Of the 57% contribution from upfront embodied carbon, the highest values are associated with the substructure & structure. This is due to the high proportions of concrete & other carbon intensive materials.

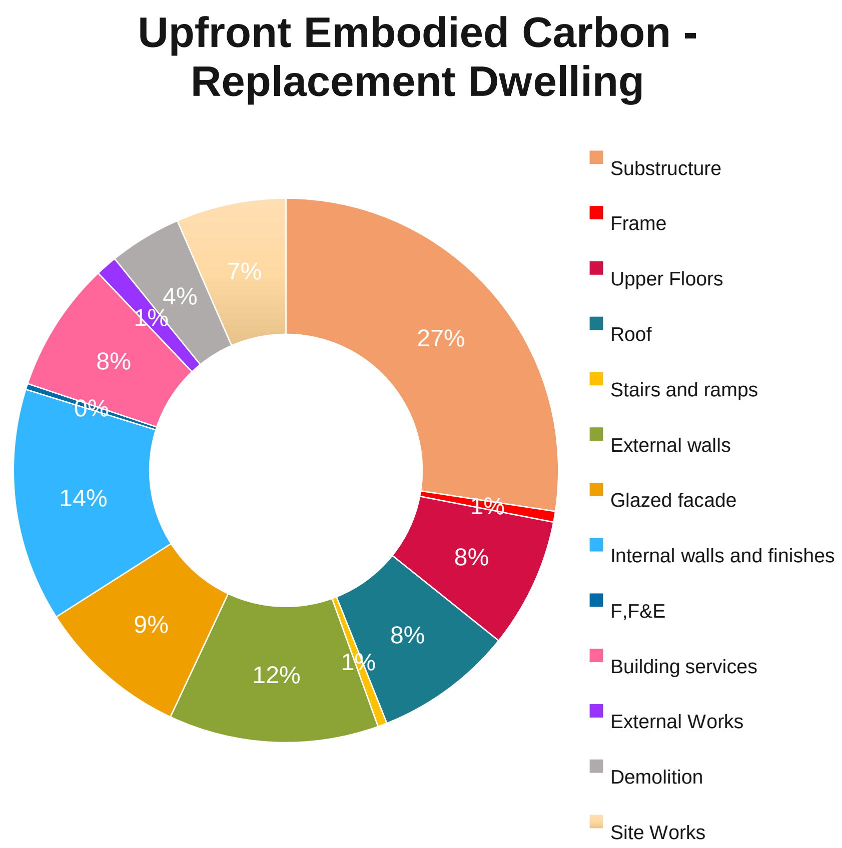


Figure 2-2: Practical completion embodied carbon breakdown of the Replacement dwelling.

Table 2-8 gives an elemental breakdown of the aggregated life cycle emissions contributing to the whole life embodied carbon emissions, alongside associated embodied carbon from practical completion for the proposed replacement dwelling.

Of the 28% contribution from the life cycle embodied carbon, the highest values are associated with the internal finishes (refurbish & replacement events) and building services (maintenance, repair, refurbish & replacement events). The embodied carbon of permanently fixed structural items remains constant between practical completion and over the life cycle.

Embodied Carbon over Life Cycle (TCO_2e)		Upfront Carbon (exc. c/seq) [A1-A5]	Life cycle impacts [B2-B5]	End of life impacts [C1-C4]	Whole Life Carbon (inc. c/seq) [A1-C4]
Substructure		66	0	14	79
Superstructure	Frame	2	0	0	2
	Upper Floors	18	0	13	10
	Roof	20	4	2	25
	Stairs and ramps	1	0	0	2
	External walls	30	0	1	31
	Glazed facade	22	19	1	38
Internal walls and Internal finishes		33	53	30	99
F,F&E		1	2	0	3
Building services		19	34	0	52
External Works		3	3	0	6
Demolition		10	0	0	10
Site works		16	0	2	17
Total Embodied Carbon		**240**	**115**	**62**	**373***
Embodied Carbon intensity (kg CO_2e/m^2 GIA)		**590**	**283**	**153**	**920***

Table 2-8: Whole life-cycle embodied carbon emissions of the Replacement dwelling.

**The whole life cycle carbon emissions are calculated after including the carbon sequestered by the development. The values for carbon at completion (A1 to A5) and carbon over the lifecycle of the project (B1 to B5 and C1 to C4) do not include sequestration.*

2.5.4 Option 3: Embodied Carbon Breakdown for the Extension and Retrofit of the Existing Dwelling

Figure 2-3 shows the embodied carbon breakdown by building element at practical completion of the construction for the retrofit for the existing dwelling with further extension.

Of the 48% contribution from upfront embodied carbon, the highest values are associated with the substructure & structure. This is due to the high proportions of concrete & other carbon intensive materials

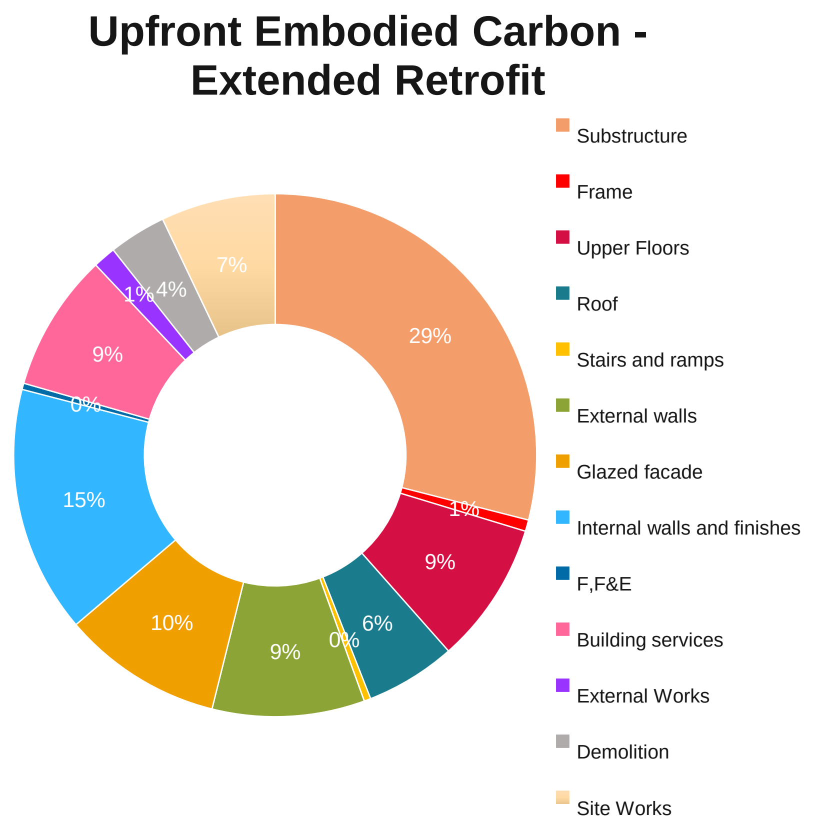


Figure 2-3: Practical completion embodied carbon breakdown of the Extension and Retrofit of the existing dwelling.

Table 2-9 gives an elemental breakdown of the aggregated life cycle emissions contributing to the whole life embodied carbon emissions, alongside associated embodied carbon from practical completion.

Of the 26% contribution from the life cycle embodied carbon, the highest values are associated with the internal finishes (refurbish & replacement events) and building services (maintenance, repair, refurbish & replacement events). The embodied carbon of permanently fixed structural items remains constant between practical completion and over the life cycle.

Embodied Carbon over Life Cycle (TCO_2e)		Upfront Carbon (exc. c/seq) [A1-A5]	Life cycle impacts [B2-B5]	End of life impacts [C1-C4]	Whole Life Carbon (inc. c/seq) [A1-C4]
Substructure		63	0	13	76
Superstructure	Frame	2	0	0	2
	Upper Floors	19	0	13	15
	Roof	12	5	1	18
	Stairs and ramps	1	0	0	1
	External walls	20	0	1	21
	Glazed facade	22	19	1	38
Internal walls and Internal finishes		33	54	30	100
F,F&E		1	2	0	3
Building services		19	34	0	52
External Works		3	3	0	6
Demolition		8	0	0	8
Site works		15	0	1	~17
Total Embodied Carbon		**217**	**117**	**60**	**356***
Embodied Carbon intensity (kg CO2e/m2 GIA)		**544**	**293**	**149**	**890***

Table 2-9: Whole life-cycle embodied carbon emissions of the Extended Retrofit.

**The whole life cycle carbon emissions are calculated after including the carbon sequestered by the development. The values for carbon at completion (A1 to A5) and carbon over the lifecycle of the project (B1 to B5 and C1 to C4) do not include sequestration.*

2.5.5 Elemental Breakdown of the Whole Life Carbon

Figure 2-4 shows the elemental comparison of the whole life cycle emissions contributing to the whole life embodied carbon emissions alongside associated operational carbon emissions. The comparison shows that the operational carbon emissions for both, the retrofitted dwelling and the retrofitted dwelling with the new extension, outweigh the embodied carbon emissions.

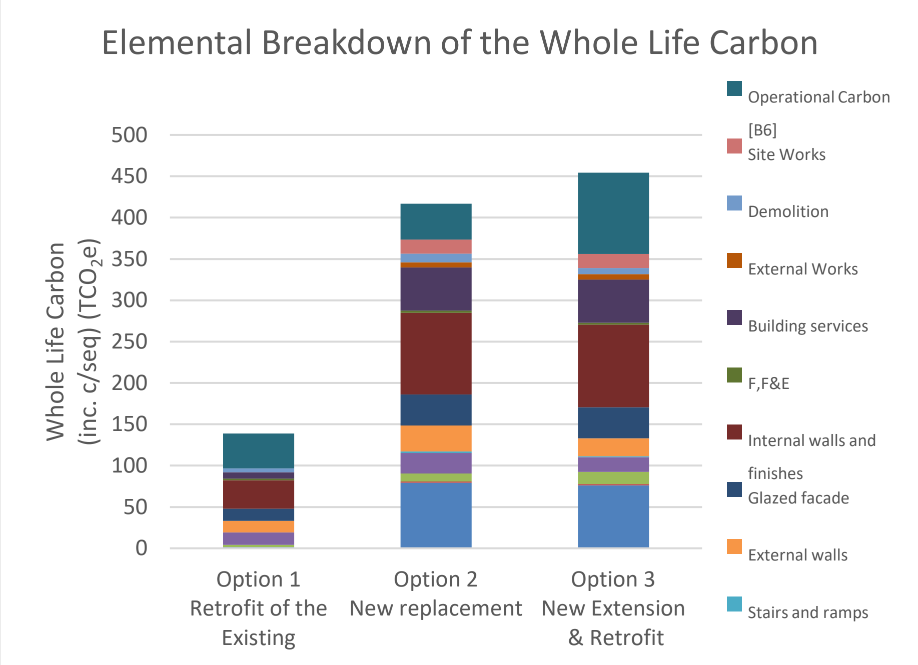


Figure 2-4: Elemental Whole Life-Cycle Carbon Comparison

2.5.6 Low Carbon Design

The following options have been incorporated into the design to reduce the carbon footprint of the proposed options:

- Local sourced (UK) heavy material like brick and blockwork
- Local sourcing of concrete – within 10-25km.
- High cement replacement GGBS (Ground Granulated Blast-furnace Slag) or PFA (Pulverised Fuel Ash) for concrete used in both substructure and superstructure.
- Timber framed glazing.
- Investigation of BDA low carbon brickwork for external walls.
- Internal finishes such as tiles (both porcelain and vinyl) and carpet to contain high recycled content.
- Low carbon paint for wall finishes.

2.5.7 Comparing to GLA Benchmark

The Greater London Authority (GLA) has benchmarks for certain building types including residential schemes. The benchmark emission rates for residences, published in March 2022, represent typical residential schemes. The WLC benchmarks include all life-cycle modules apart from B6, B7 (operational energy and operational water) and module D.

Figure 2-5 shows all three options for 9D The Grove development with respect to the upfront and lifecycle embodied carbon emissions in comparison to the GLA benchmarks. The results show that all the options for 9D The Grove development currently meet and better both the upfront and life-cycle embodied carbon performance benchmarks set by the GLA. Generally, the upfront embodied carbon performance is slightly better for the extension and retrofitted dwelling option as compared to the new replaced dwelling scenario.

Contrarily, the life-cycle embodied carbon performance for the new replaced dwelling is better than that of the extension and retrofitted dwelling option. Overall, the new replacement option and the retrofitted & extension option perform similarly.

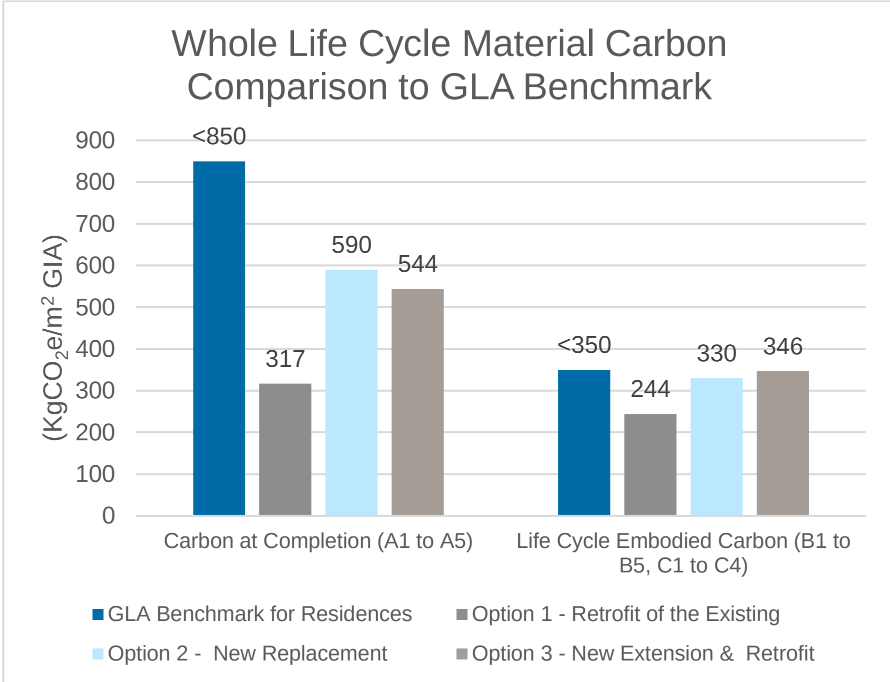


Figure 2-5: Whole Life-Cycle Material Carbon Comparison with GLA benchmark

2.5.8 Whole Life-Cycle Carbon

Whole Life-Cycle Carbon considers the combination of the embodied carbon emissions and the operational carbon emissions of the proposed development.

The operational emissions include the operational energy use, corresponding with life-cycle module B6. The operational water use, corresponding to module B7 are not included in this assessment.

The operational carbon emissions for the Option 1 – Retrofit of the Existing Building and Option 2 – Replacement of the development, were not calculated by Cundall for this assessment. These are extracted from the 'Energy statement' provided by Iceni Projects Limited on behalf of Nir Cohen. The aforementioned report assumes that under the Option 2 – Replacement scenario, a highly efficient air source heat pump (ASHP) system will be employed. Whereas an air source heat pump (ASHP) system with typical manufacturer specifications will be employed under the Option 1 – Retrofit of the Existing Building scenario. Whereas, for the Option 3 – Extension and retrofit of the existing dwelling assumes the same systems as those prescribed for the retrofit scenario.

The total operational carbon emissions for Option 1 - Retrofit of the existing dwelling is estimated to amount to 42 tonnes CO_2e during the life cycle of the development. This is similar to the total operational carbon emissions for Option 2 - Replacement dwelling, estimated to amount to 43 tonnes CO_2e during the life cycle of the development, even though the GIA of the Option 1 – Retrofit dwelling is approximately 50% less than that of Option 2. The Option 3 that is a combined scenario is estimated to amount to 98 tonnes CO_2e during the life cycle of the development which is the highest among all 3 options.

Tonne CO_2e	Option 1 Retrofit of Existing Building	Option 2 Replacement	Option 3 Extension & retrofit
Operational Energy Use, B6	42	43	98

Table 2-10: Operational Carbon emissions (Tonne CO_2e)

$KgCO_2e/m^2$	Option 1 Retrofit of Existing Building	Option 2 Replacement	Option 3 Extension & retrofit
Operational Energy Use, B6	243	107	246

Table 2-11: Operational Carbon emissions ($KgCO_2e/m^2$ GIA)

To give context to these emissions in relation to the GIA of the whole development, the carbon emissions in $kgCO_2e/m^2$ are displayed in Table 2-11.

The operational emissions account for 30% of the whole life cycle emissions for the Option 1 - Retrofit of the existing dwelling whereas the operational emissions account for 10% of the whole life cycle emissions for the Option 2 - Replacement dwelling. While the operational emissions for Option 3 - New extension and retrofit of the existing building amount to 22% of the whole life cycle emissions.

The predicted benefits and loads beyond the system boundary have been included in the life cycle breakdowns, but the results for Module D are not included in the total results.

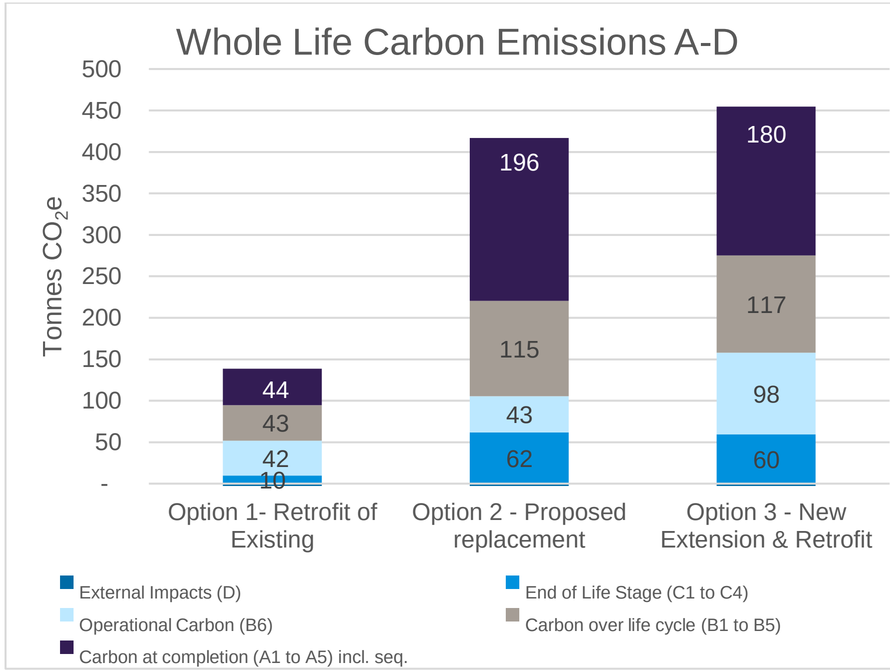


Figure 2-6: Whole Life-cycle Carbon emissions for Option 1 - Retrofit of the existing dwelling, Option 2 - Replacement dwelling and Option 3 - Extension and retrofit of the existing dwelling.

3.0

Conclusion

Conclusion

3.1 Conclusions

Overall, the replacement dwelling showed highest upfront embodied carbon emissions compared to its refurbished and/or extended counterparts. This can be attributed to the fact that refurbished options retain the existing structure.

The comparison of results for all three options over a 60-year lifecycle is summarised in Figure 3 and Table 3. For like-to-like comparison in terms of area, the figure demonstrates that the carbon gap between the replacement dwelling, and the extension of the retrofitted dwelling shifts after 23 years, whereby the new replacement continues to outperform the retrofitted and extended dwelling over the lifecycle. This results in a significant carbon gap at the end of lifecycle between the two options.

Hence, despite the retrofitted dwelling alone and the retrofitted dwelling with the new extension, both demonstrating lower upfront embodied carbon emissions, the higher operational carbon emissions would more than outweigh this over the life cycle and, therefore, offer best carbon payback with the new replacement dwelling.

Total Whole Life-Cycle Carbon		Tonnes CO_2e	$kgCO_2e/m^2$ GIA
Option 1 **Retrofit of Existing Building**	Upfront Embodied Carbon (A1-A5)	55	317
	Whole Life Carbon (A-C)	139	804
Option 2 **Demolition & New Replacement**	Upfront Embodied Carbon (A1-A5)	240	590
	Whole Life Carbon (A-C)	417	1,026
Option 3 **Extension & retrofit**	Upfront Embodied Carbon (A1-A5)	217	544
	Whole Life Carbon (A-C)	454	1,136

Table 3: Whole life carbon comparison showing 9D The Grove's Retrofit of existing dwelling, Replacement dwelling and Extension and retrofit of existing dwelling.

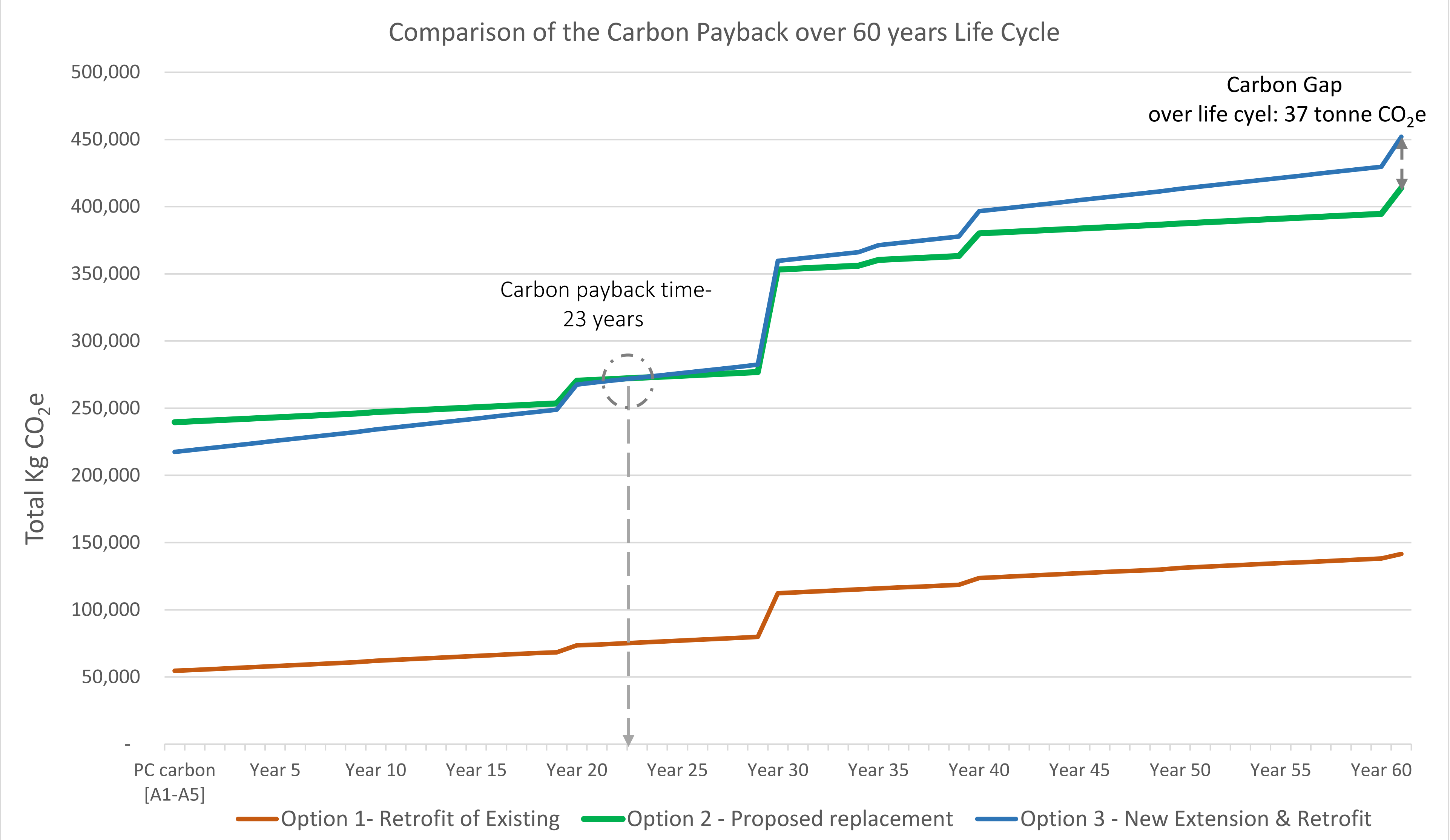


Figure 3: Comparison of the aggregated carbon emissions over 60 years Life Cycle

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