Whole Life Carbon Assessment

46 Maresfield Gardens

For Russell Ambrose

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ecolytik

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Contents

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1 Executive Summary

A Whole Life Carbon Assessment has been carried out for the application site at 46 Maresfield Gardens in Hampstead, within the London Borough of Camden.

The methodology followed in preparing this report is in line with the RICS professional statement (2017) for undertaking detailed carbon assessments, as per current GLA guidance. The RICS Whole life carbon assessment for the built environment follows the European standard EN 15978.

1.1 Development scenarios

For comparison purposes, three assessments scenarios were carried out for the site, as follows:

1. **Existing building with minor upgrades**: Internal alterations and improvements to finishes, light fittings, kitchens and bathrooms, together with replacement of the existing gas boiler for improved efficiency. The GIA of this scenario is 144m^2.
2. **Major Refurbishment & extension**: This included partial demolition, refurbishment and extension of the existing dwelling. Existing building elements would be refurbished to standards for existing thermal elements stipulated in Part L1 2021 of Building Regulations, while potential extension elements would be designed to exceed Part L1 standards for new-build thermal elements. The heating system will be upgraded to include an air source heat pump. The GIA of this scenario is 436m^2.
3. **Proposed demolition & new-build:** This included retention of the building's basement, rebuild the ground floor rear extensions, together with construction of new-build ground plus two storeys building exceeding Part L efficiency standards. Air source heat pump (ASHP), mechanical ventilation with heat recovery (MVHR) and photovoltaics are proposed. The GIA of this scenario is 436m^2. This scenario represents the proposed scheme.

For the purpose of the analyses, the embodied carbon has been calculated from cradle to practical completion (handover), which covers stages A1 – A5 (Product and Construction), Stage B (Use Stage, excluding module B6) as well as stages C1-C4 (End-of-Life) for a 60-year design life in line with policy and guidance. Stage D (Benefits and loads beyond the system boundary) has not been a focus of this assessment as the same principles could in theory be applied to all assessment scenarios, with similar benefits beyond the system boundary.

Operational carbon emissions (B6) were evaluated with the use of the SAP (for regulated carbon) and PHPP (for unregulated carbon) for the scheme. Operational carbon emissions (B7) associated with water use were based on water consumption rates in line with current policy.

1.2 Results

The performance of all scenarios was compared in terms of embodied carbon against GLA's latest guidance and benchmarks (March 2022). The embodied carbon emissions for proposed scheme at 46 Maresfield Gardens were found to align with GLA's benchmark (modules A-C excluding B6/B7) for all scenarios (Figure 1). With the use of measures such as recycled content in the concrete and environmentally friendly refrigerants, both the refurb & extension as well as the new-build options were found to meet the embodied carbon target with Camden's emerging Local Plan (reg 18).

The lowest embodied carbon scenario would be to implement only minor upgrades to the existing building. The refurbishment and extension scenario was found to result in lower embodied carbon than the demolition and new-build scheme. The comparison is illustrated in Figure 1.

However, when operational carbon emissions over a 60-year timeframe are considered, the new-build scenario was found to perform more favourably than the refurbishment & extension as well as the existing building scenarios (Figure 2).

As per industry's guidance, carbon emissions should be assessed over the whole life cycle of a project, with a typical study period of 60 years. The analysis for this site showed that the demolition and new-build scenario will be beneficial in terms of carbon after 24 years when compared to an equivalent refurb and extension scheme and 7 years when compared against the existing building on a per m^2 basis.

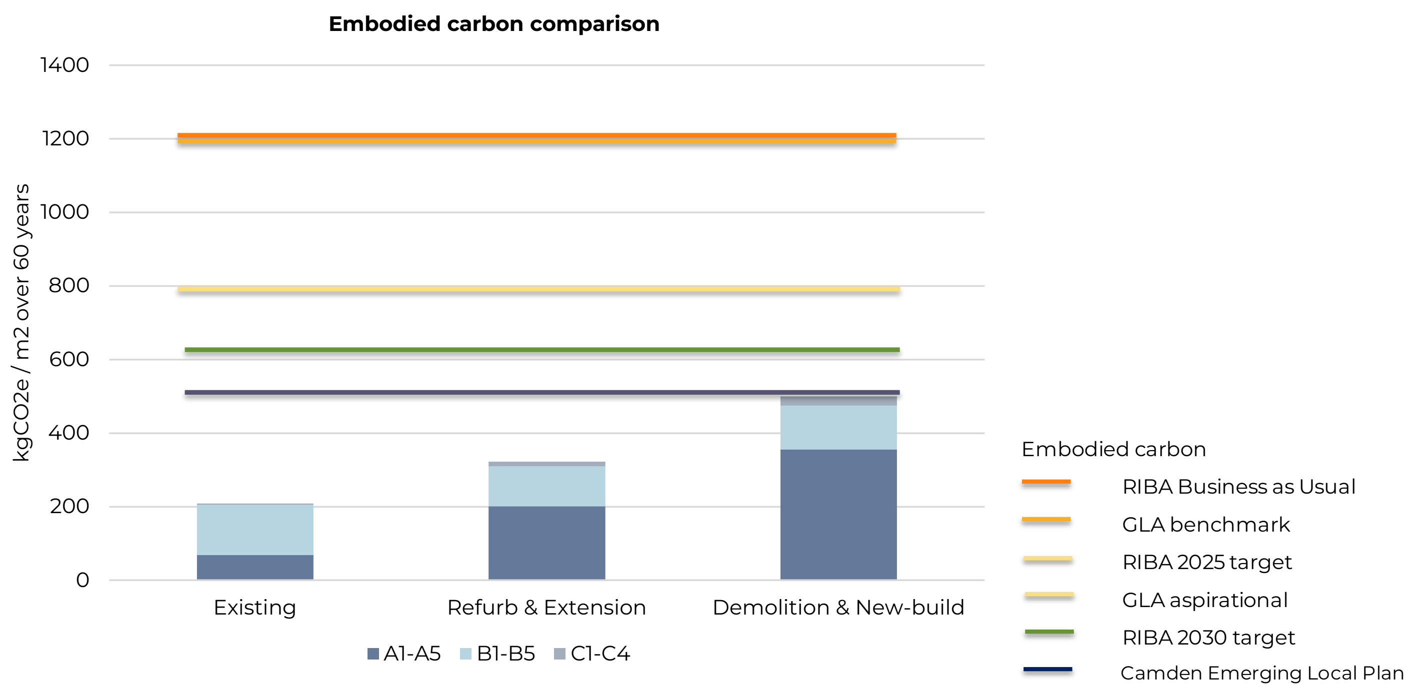


Figure 1. Embodied Carbon emissions comparison with benchmarks for all scenarios for 46 Maresfield Gardens.

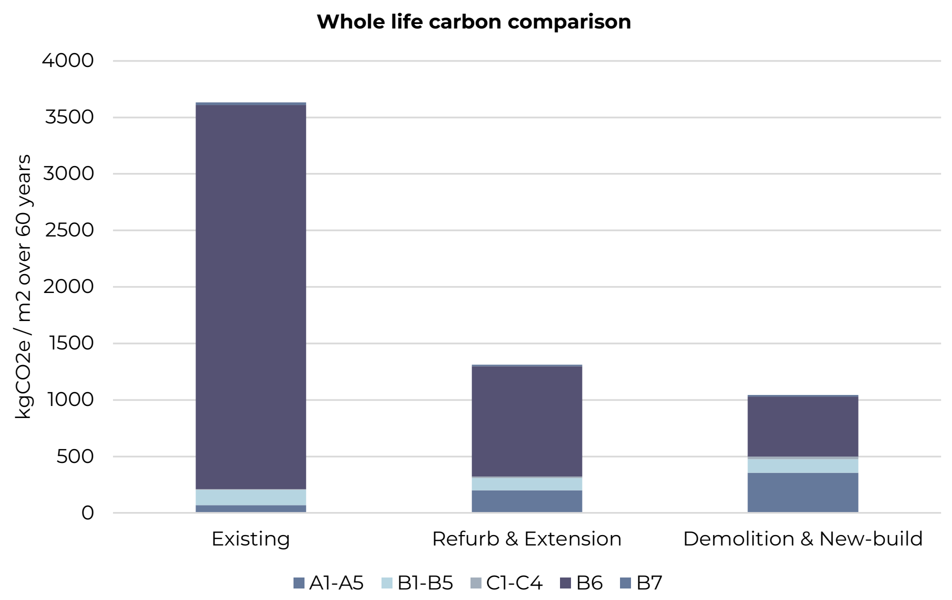


Figure 2. Whole life carbon comparison between all scenarios.

Table 1. Whole life carbon emissions for the three scenarios for each lifecycle module over 60 years.

Emissions by module ($kgCO_2e/m^2$)	A1-A5	B1-B5	B6	B7	C1-C4	Totals
Existing building	69	137	3,401	16	4	3,626
Refurb and extension	201	108	974	16	13	1,313
Demolition and new-build	356	119	529	16	25	1,045

2 Introduction

2.1 Site

46 Maresfield Gardens is located in Hampstead, in the London Borough of Camden. The site is within a predominantly residential setting and currently comprises a two-storey plus basement mid-century dwelling. Residential properties can be found to the immediate north and east of the site, as well as across Maresfield Gardens to the west. The site closely adjoins an underground railway line and exhaust vent to the south.

The proposed scheme comprises demolition of the existing dwelling and erection of a replacement dwelling with three above ground storeys. The existing garage at basement level will be retained and utilised for storage. The site location plan is shown in Figure 3.

2.2 Assessment approach and practical considerations

The key scenarios explored for their whole life carbon impacts on the application site were:

1. Existing building with minor refurbishment: minor internal alterations to finishes, fittings and a new gas boiler.
2. Refurbishment and extension: part demolition, upgrading retained building elements by installing insulation, new build extension designed to exceed Part L1 2021 fabric standards, and installation of air source heat pump system for space heating and hot water.
3. Demolition and new-build: retention of the basement and demolition of the structure above ground. Construction of new building exceeding Part L1 2021 efficiency standards, installation of MVHR, photovoltaics and air source heat pump.

The existing building scenario practically involves minimal interventions and with the exception of upgrading the boiler, the remaining works entail mainly internal upgrades and would not typically incur significant embodied carbon emissions. Nevertheless, this possibility for the site was explored to form an existing baseline.

In order to enable a comparison between a refurbishment and extension design versus a demolition and new-build design for the application site, certain assumptions were made during early stages of the project in order to inform the carbon emissions calculations.

There is often a requirement for significant levels of intervention to an existing building to upgrade its fabric performance and systems, as well as to enable delivery of a scheme that would be directly comparable to a demolition and new build scheme. Therefore, the assessment included for part demolition, part retention of the existing building, together with a theoretical extension to the rear of the site to achieve the same overall floor area as the proposed development.

For this analysis, it was assumed that it is feasible to insulate all retained elements, salvage at least two thirds of the existing building's substructure and superstructure without any notable technical constraints. In reality, it would be appreciated that meeting the u-values set out within Part L1 2021 may not be fully feasible during a refurbishment for all retained elements (e.g. insulating fully an existing floor may cause challenges with levels). Therefore, the operational carbon emissions of the refurbishment and extension scenario may be higher than those included in this report.

The potential extension of the refurb and extension design scenario was modelled on the basis that it can be designed and constructed with similar materials and specifications as the new-build scenario. The rationale for this would be to enable a direct comparison between these two scenarios and to not assume that one design may have wider material and system options available than the other.

End-of-Life scenarios were assumed to be the same for all design scenarios for the application site because principles of recycling and reuse could be implemented to the same extent for all options. However, a new-build scheme provides greater flexibility in terms of its design and construction that may enable more straightforward deconstruction, reuse and potentially recycling of materials at their end of life. This slight advantage of a new-build scheme was not factored into the analysis as a worst-case approach.

Figure 3. Approximate site location of 46 Maresfield Gardens.

3 Methodology

The methodology followed in calculating the embodied carbon emissions is aligned with the RICS professional statement (PS) for undertaking detailed carbon assessments. The RICS Whole life Carbon Assessment for the Built Environment follows the European standard EN 15978. The RICS PS has been updated and its latest issue was published in November 2023, coming into effect from 1 July 2024. However, at the time of this assessment, the GLA continue to recommend the use of RICS guidance 2017 edition, which was used to inform this assessment.

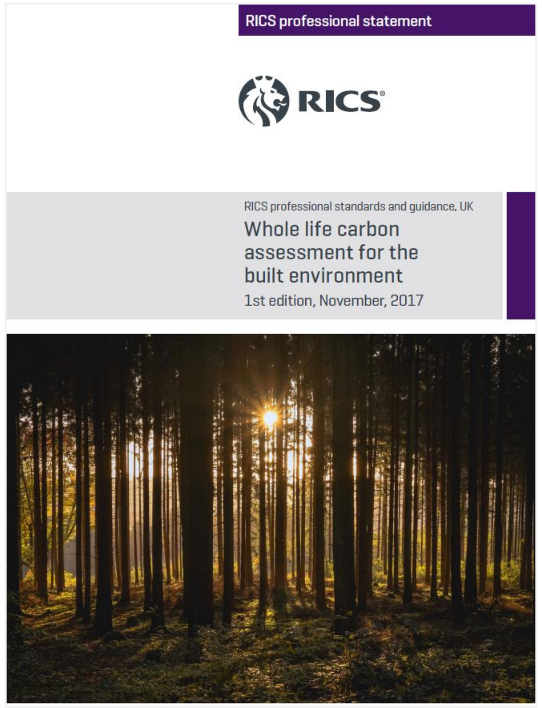
The study period of the analysis was set to 60 years in line with RICS PS. Operational carbon emissions from energy use have been predicted with the use of SAP and PHPP for the proposed scheme. Benchmarked data per m^2 from similar past projects were used to inform the operational emissions of the other two scenarios for the site.

Quantity information has been derived from information received by the team or measurements have been made from the architectural drawings as per methodology set out by the RICS PS. Where sufficient detail is not available, conservative estimations have been made.

3.1 Life cycle stages

The life cycle stages covered by the RICS methodology refer to EN 15978, which includes a modular approach to a built asset's life cycle, breaking it down into different stages. The four main modules are Product stage [A1 – A3], Construction Process stage [A4 – A5], Use stage [B1 – B7] and End of Life stage [C1 – C4]. Module D consists of the potential environmental benefits or burdens of materials beyond the life of the project, this is usually reported separately to the cradle to grave modules [A – C].

Table 2 shows the life-cycle stages that were considered for the assessment. Table 3 illustrates the life cycle stages and terms used to describe the various types of emissions. Embodied carbon only considers lifecycle stages A1 to B5 and C1 to C4.



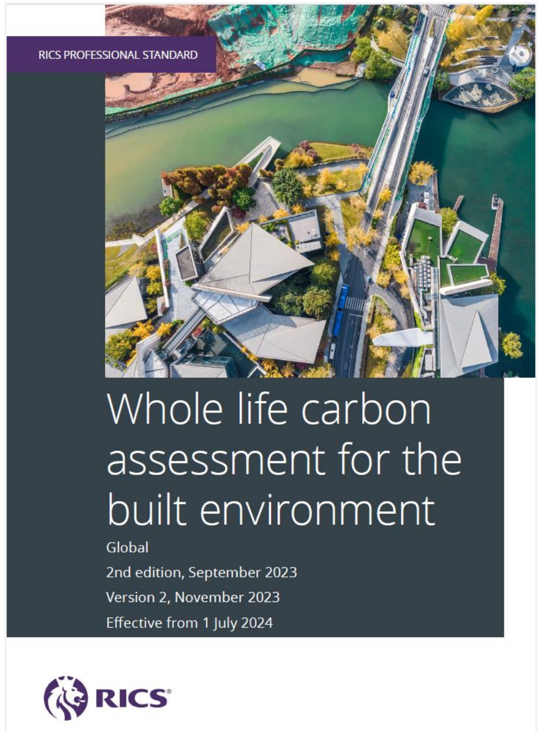


Table 2. Life cycle stages considered in the whole life carbon assessments.

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x

Table 3. Definitions of types of carbon emissions.

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D
Cradle to gate																		
Upfront / Cradle to site																		
Embodied carbon (excludes B6-B7)																		
					Use stage carbon													
										Operational								
Whole Life Carbon / Cradle to grave																		
																Beyond lifecycle		

3.2 Building elements

The assessment considers the elements presented in Table 4.

Sequestered (biogenic) carbon, in particular from the use of timber products, is deducted from the GWP emissions in A1-A3, and in C3 the same amount of carbon is added as it is released back to the atmosphere. This results in no overall impact on the total carbon emissions.

Embodied carbon is challenging to calculate for many MEP systems due to a lack of detailed available data. Where manufacturer specific data is not available figures for embodied carbon have been taken from the closest matching system within the eToolLCD database and considering the latest guidance from CIBSE TM65.

3.3 Software

The software used for the assessment is eToolLCD, which follows BS EN 15978, is IMPACT-compliant and BRE certified and listed in GLA's Whole Life Carbon Assessment guidance document (March 2022) as an acceptable software to use for whole life carbon assessments.

It should be noted that the whole life carbon assessment predictions conducted, by their very nature, cannot be exact. It is not possible to track all the impacts associated with a product or service back through history, let alone doing this accurately. eToolLCD software has been built and tested to enable informed decisions when comparing design scenarios. Generic cost and environmental impact coefficients do not necessarily correspond to those of individual brands of the same product or service due to differences within industries in the way these products and services are delivered. However, the approach and methodology adopted is generally deemed acceptable by Local Authorities, industry bodies and the GLA.

Table 4. Building elements considered in the assessments as per RICS standard.

Group no.	Group	Building Element	Applicable	Included
0	Demolition & facilitating works	0.1. Toxic / hazardous / contaminated material treatment	N	N
		0.2. Major demolition works	Y	Y
		0.3. & 0.5. Temporary / enabling works	N	N
		0.4. Specialist groundworks	N	N
1	Substructure	1.1. Substructure	Y	Y
2	Superstructure	2.1. Frame	Y	Y
		2.2. Upper floors incl. balconies	Y	Y
		2.3. Roof	Y	Y
		2.4. Stairs & ramps	Y	Y
		2.5. External walls	Y	Y
		2.6. Windows & external doors	Y	Y
		2.7. Internal walls & partitions	Y	Y
		2.8 Internal doors	Y	Y
3	Finishes	3.1 Wall finishes	Y	Y
		3.2 Floor finishes	Y	Y
		3.3 Ceiling finishes	Y	Y
4	FFE	4.1 Fittings, furnishings & equipment	Y	Y
5	Building services / MEP	5.1–5.14 Services	Y	Y
6	Prefabricated Buildings and Building Units	6.1 Prefabricated buildings and building unit	N	N
7	Work to existing building	7.1 Minor demolition and alteration works	Y	Y
8	External works	8.1 Site preparation works	Y	Y
		8.2 Roads, paths, paving's and surfacing's	Y	Y
		8.3 Soft landscaping, planting and irrigation systems	Y	Y
		8.4 Fencing, railings and walls	Y	Y
		8.5 External fixtures	Y	Y
		8.6 External drainage	Y	Y
		8.7 External services	Y	Y
		8.8 Minor building works and ancillary buildings	N	N

3.4 Assessment information

The assessment included all the upstream and downstream processes needed to provide the primary function of the structure from construction, demolition and disposal. The inventory includes the extraction of raw materials or energy and the release of substances back to the environment or to the point where inventory items exit the system boundary either during or at the end of the project life cycle.

The EN15978 cut-off criteria were used to ensure that all relevant potential environmental impacts were appropriately represented:

- Mass: if a flow is less than 1% of the mass at either a product-level or individual-process level, then it has been excluded, provided its environmental relevance is not of concern.
- Energy: if a flow is less than 1% of the energy at either a product-level or individual-process level, then it has been excluded, provided its environmental relevance is not a concern.
- The total of neglected input flows per module, e.g. per module A1-A3, A4-A5, B1-B5, B6-B7, C1-C4 and module D shall be a maximum of 5% of energy usage and mass.
- Environmental relevance: if a flow meets the above criteria for exclusion but is considered to potentially have a significant environmental impact, it has been included. All material flows which leave the system (emissions) and whose environmental impact is higher than 1% of an impact category, have been included.

Table 5 provides initial information on the assessment approach, while more detailed information on what has been included in the model is presented in Appendix A.

Table 5. Key assumptions and principles used to carry out the assessments.

Environmental Indicator	Lifecycle carbon CO_2e
Study Period	60-year design life.
Functional Unit	The Functional Unit for embodied carbon is shown in $kgCO_2e$ per m^2 of floor area (GIA)
	The GIA was taken from the architect's drawings.
System Boundary	In accordance with BS EN 1579:2011
Software Tools	eTool LCD
Assessment Scope	Building and site area
Elements Considered	All modules included, in accordance with RICS PS. Module D not discussed in detail in this comparative study.
Materials Specification	Building elements such as wall, window, door areas, etc measured from architectural drawings (by Square Feet Architects).
	Construction based on feedback from the design team.
	Material specifications based on feedback from design team.
Refrigerant Leakage	CIBSE TM65 data used for heat pump refrigerant impacts. R410 refrigerant modelled for initial design.
Operational Energy Consumption	B6 Operational Emissions are estimated within SAP and PHPP software and benchmarked data.
	Regulated carbon emissions for new-build were taken from the Energy Statement. Regulated carbon emissions for the refurb and extension scenario derived from the use of Part L1 2021 u-values for existing elements and proposed best practice U-values for extension elements within SAP software for similar past projects. Upgrading lighting and heating systems also assumed for the refurbishment and extension. scenario.
	The existing scenario emissions were derived from SAP for similar past projects, with existing building's u-values together with a new gas boiler of improved efficiency.
	Unregulated carbon emissions derived from PHPP modelling assuming the use of energy efficient equipment for all development scenarios (estimated at 35 $kWh/m^2.year$).
M&E systems	Assumed air source heat pump for refurb and extension and demolition and new-build scenarios for a low carbon retrofit and a low carbon new-build design. Closest matching system selected from eTool's database and with information from CIBSE TM65. The existing building scenario included the provision of a new gas boiler.
Water Consumption	Included based on a water consumption of 105 l/p/d to reflect the installation of water efficient fittings for all scenarios.

The following sources of information provided by the client and design team were used to inform the inventory of the assessment:

- Proposed U-values for the new-build development scenario set out within Appendix A of the accompanying Energy Statement. These U-values were also modelled for the extension elements of the refurbishment and extension assessment scenario for consistency.
- The existing house is cavity brick wall and no insulation to any building elements. These building elements would have to be upgraded to the U-values set out within Table 4.2 of Part L, if the existing building was to be undergo major refurbishment and extension.

3.5 Assessment scenarios

Three assessments were carried out for the site, as follows:

1. **Existing building with minor refurbishment**: Internal alterations and improvements to finishes, fittings, kitchens and bathrooms, together a new gas boiler replacement for improved efficiency. The GIA of this scenario is 144m^2.
2. **Major refurbishment & extension**: This included partial demolition, refurbishment and extension of the existing dwelling. Existing building elements would be refurbished to standards for existing thermal elements stipulated in Part L1 2021 of Building Regulations, while potential extension elements would be designed to exceed Part L1 standards for new-build thermal elements. The heating system will be upgraded to include an air source heat pump. The GIA of this scenario is 436m^2.
3. **Proposed demolition & new-build:** This included retention of the building's basement, rebuild the ground floor rear extensions, together with construction of new-build ground plus two storeys building exceeding Part L efficiency standards. MVHR will be provided. The heating system would include an air source heat pump system. A photovoltaic array is proposed at roof level. The GIA of this scenario is 436m^2.

The difference to the extent of demolition between Scenarios 2 and 3 is that in scenario 2, only one third of the building is demolished while in scenario 3, the building above ground is demolished and only the basement is retained. Table 6 shows the key differences in the modelling inputs between the three scenarios.

Table 6. Modelling inputs for the three design scenarios.

Operational carbon	**Existing building**	**Refurb and Extension**	**Demolition and new-build**
New external walls U-value	n/a	0.18 W/m^2.K	0.15 W/m^2.K
Retained walls U-value	2.1 W/m^2.K	0.55 W/m^2.K	-
Roof U-value	2.3 W/m^2.K	0.15W/m^2.K	0.1 W/m^2.K
Floor U-value	0.5 W/m^2.K	0.18 W/m^2.K	0.1 W/m^2.K
Window U-value	2.8 W/m^2.K	1.4 W/m^2.K	1.2 W/m^2.K
Heating system	New gas boiler	Air source heat pump	Air source heat pump
Ventilation system	Intermittent extract fans	Intermittent extract fans	MVHR
Air permeability	>15 m^3/m^2.h	15 m^3/m^2.h	3 m^3/m^2.h
Embodied carbon	**Existing building**	**Refurb and Extension**	**Demolition and new-build**
Demolition emissions	n/a	14,880 kgCO_2e	29,670 kgCO_2e
Concrete piles	n/a	278m	415m
External walls	n/a	326m^2 new-build wall 162m^2 of retained wall for retrofitting insulation	486m^2 new-build wall
Roofs	n/a	148m^2 new-build roof 73m^2 of retained roof for retrofitting insulation	221m^2 new-build roof
Floors	n/a	76m^2 of upper floor to refurbish 72m^2 of retained ground floor for retrofitting insulation	New floors throughout
Internal walls	n/a	147m^2 new-build internal wall	219m^2 new-build lightweight Metsec wall
Finishes	Internal wall and ceiling finishes	Ceiling and floor finishes throughout	Finishes for all walls, floors and ceilings
Kitchens, bathrooms and lighting, wiring/plumbing	New installation	New installation	New installation

4 Results

This section of the report provides the key results of the analysis. Detailed results are provided in Appendix B.

4.1 Existing building with minor refurbishment

With minor internal upgrades to the existing building internally, the majority of the whole life carbon emissions would be from the operational stage. Upgrading the existing gas boiler to a new one would slightly reduce the carbon emissions but this scenario would not enable the site to better align with government's targets to achieve net zero carbon by 2050. The use of gas boilers would not enable the existing building to benefit from the decarbonisation of the electricity grid.

The whole life carbon emissions of this scenario were estimated to be 3,626 kgCO_2/m^2 over the 60-year study period.

4.2 Major refurbishment and extension

The key contributing elements of whole life carbon emissions for the major refurbishment and extension scenario, considering modules A-C, are identified in Figure 4.

The majority of the carbon emissions are Operational stage emissions (modules B6 and B7), representing 74% of whole life carbon emissions for this design scenario.

A1-A3 Product Stage account for 4% of emissions, while upfront embodied carbon (module A1-A5) accounts for approximately 15% of whole life carbon emissions. Module B in-use stage (excluding B6 and B7 which are classified as operational carbon) constitute circa 8% of the overall emissions. End-of-life emissions (module C) were found to be approximately 2% of the whole life carbon emissions for this design scenario.

The whole life carbon emissions for this design scenario were found to be 1,313 kgCO_2/m^2 over the 60-year study period.

4.3 Proposed demolition and new-build

As the new-build scheme can be designed to be more energy efficient than a refurbishment and extension scheme, the operational carbon emissions over a 60-year period claim a smaller proportion of the lifetime carbon emissions (53% for modules B6 and B7 as shown in Figure 5).

Module A (upfront carbon) was found to claim a higher proportion of the overall emissions for the new-build scheme (34%). Module B in-use stage (excluding B6 and B7 which are classified as operational carbon) constitute circa 11% of the overall emissions for this design scenario. End-of-life emissions (module C) were found to be approximately 3% of the whole life carbon emissions for this design scenario.

The whole life carbon emissions for this design scenario were found to be 1,045 kgCO_2/m^2 over the 60-year study period, which is lower than the refurbishment and extension scenario.

The following subsection of the report presents a timeline comparison of the cumulative emissions for the three scenarios.

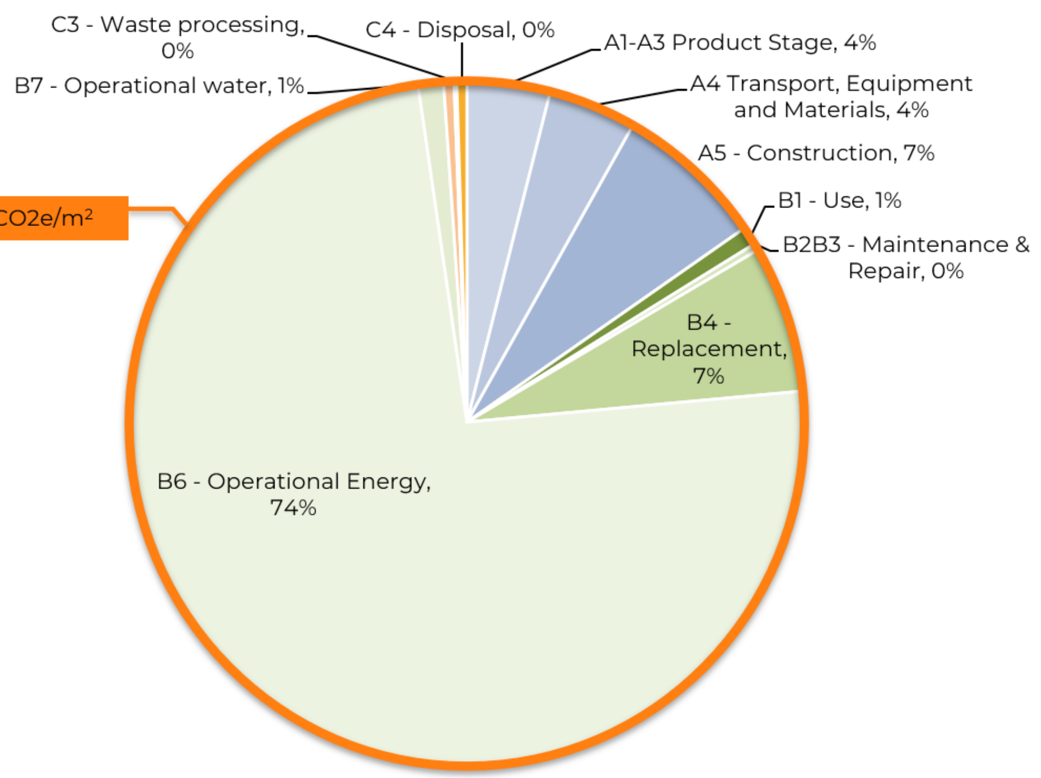


Figure 4. Distribution of emissions for the refurbishment & extension assessment.

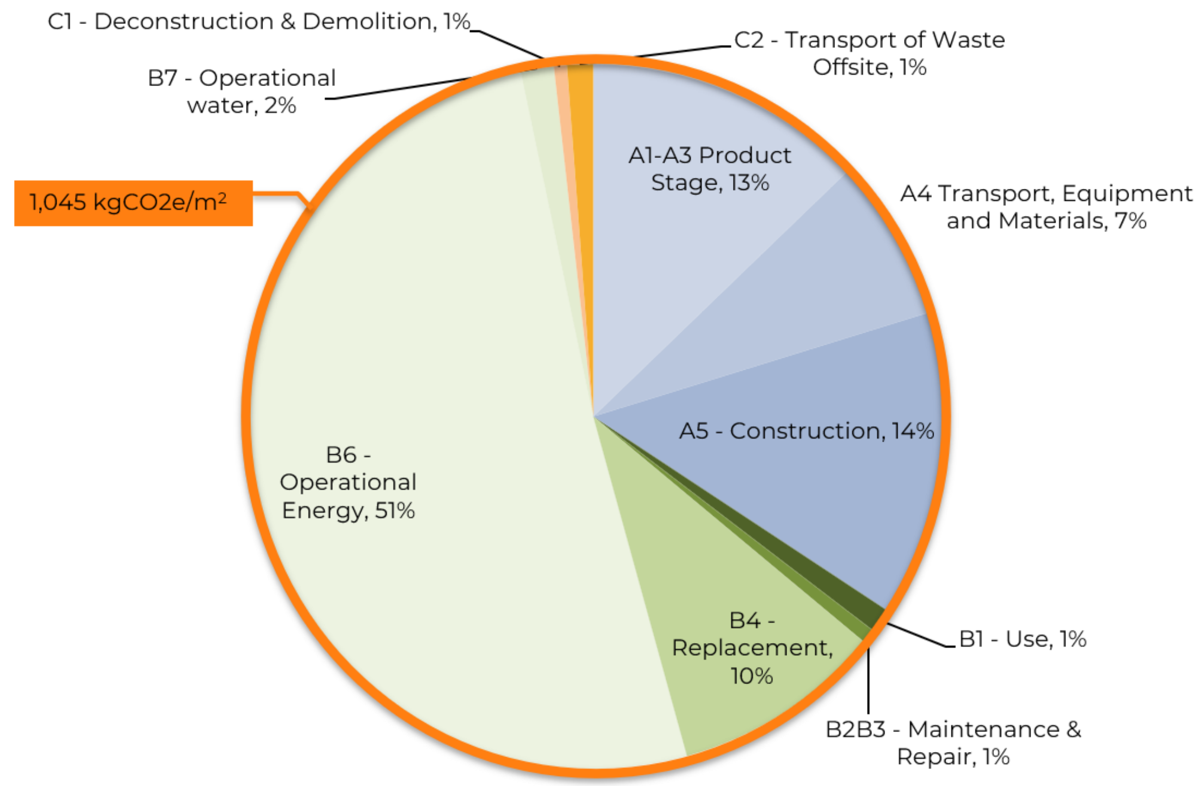


Figure 5. Distribution of emissions for the demolition and new-build assessment.

4.4 Whole Life Carbon performance comparison

Analysis was carried out to compare the cumulative whole life carbon emissions of the three scenarios for the application site at 46 Maresfield Gardens.

As per industry's guidance, carbon emissions should be assessed over the whole life cycle of a project, with a typical study period of 60 years. The emissions were normalised to the floor area of each scenario to provide a meaningful comparison of the three options.

The analysis showed that the refurbishment and extension as well as the demolition and new-build scenarios for the site would break even in terms of cumulative carbon emissions with the existing building and minor refurbishment scenario in approximately 7 years.

The demolition and new-build scenario will be beneficial in terms of whole life carbon emissions after 24 years compared to the refurbishment and extension scenario, when all carbon emissions are taken into account (Figure 6). This indicates that in terms of lifecycle carbon emissions, the demolition and new-build scenario is likely to result in the most favourable outcome for the site in the long run.

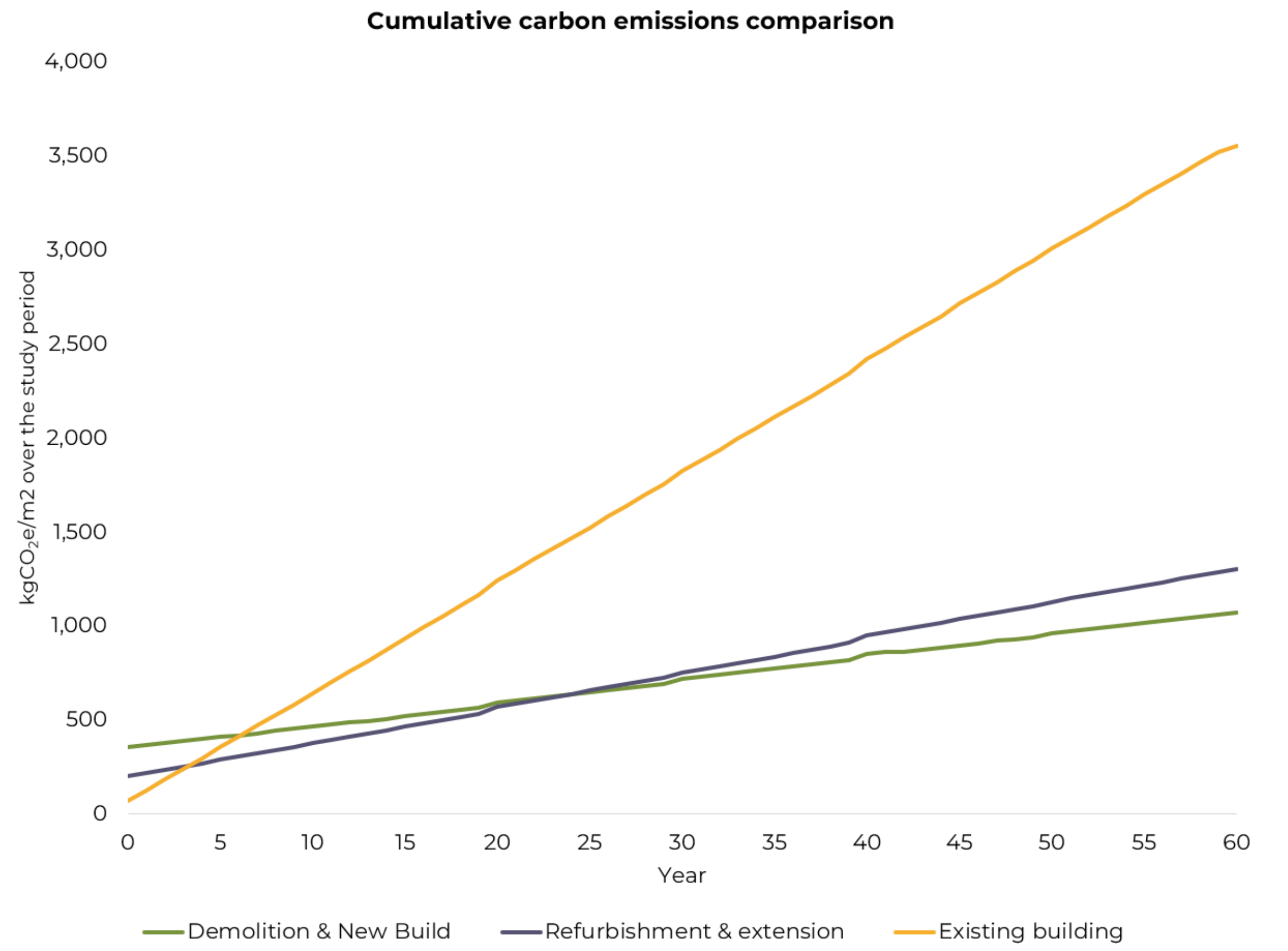


Figure 6. Cumulative carbon emissions for the three scenarios.

5 Actions to reduce embodied carbon

The proposed development has been designed in a way that could reduce both embodied and operational carbon emissions. Timber frame construction and structural insulated panels are proposed for the superstructure that reduces embodied carbon impacts. The main carbon hotspots of the proposed development were the specification of the concrete bored piles and ground floor slab, together with the refrigerant that will have to be used as part of the air source heat pump system.

The results of the assessment are based on preliminary information at RIBA Stage 2 and include certain assumptions on materials specifications, service life and transport distances which were informed by RICS guidance. Based on the current assessment at this project stage, the key actions that the design team will aim to adopt post-planning include:

- Use of concrete with blast furnace slag or other cement replacements in the mix in proportions higher than those stipulated in RICS guidance. 50% GGBS is currently targeted. Subject to structural engineering input, this would provide approximately 4% embodied carbon savings (20 $kgCO_2e/m^2$).
- Use of more environmentally friendly refrigerants for the heat pump, such as R454B (GWP 466). The development could achieve embodied carbon savings of circa 7% (42 $kgCO_2e/m^2$).
- Maximising recycled content of steel would not provide benefits given the high recycling rates of steel currently in the UK (RICS guidance advises this is 97%).

The impact on the findings for implementing these actions is shown Figure 7.

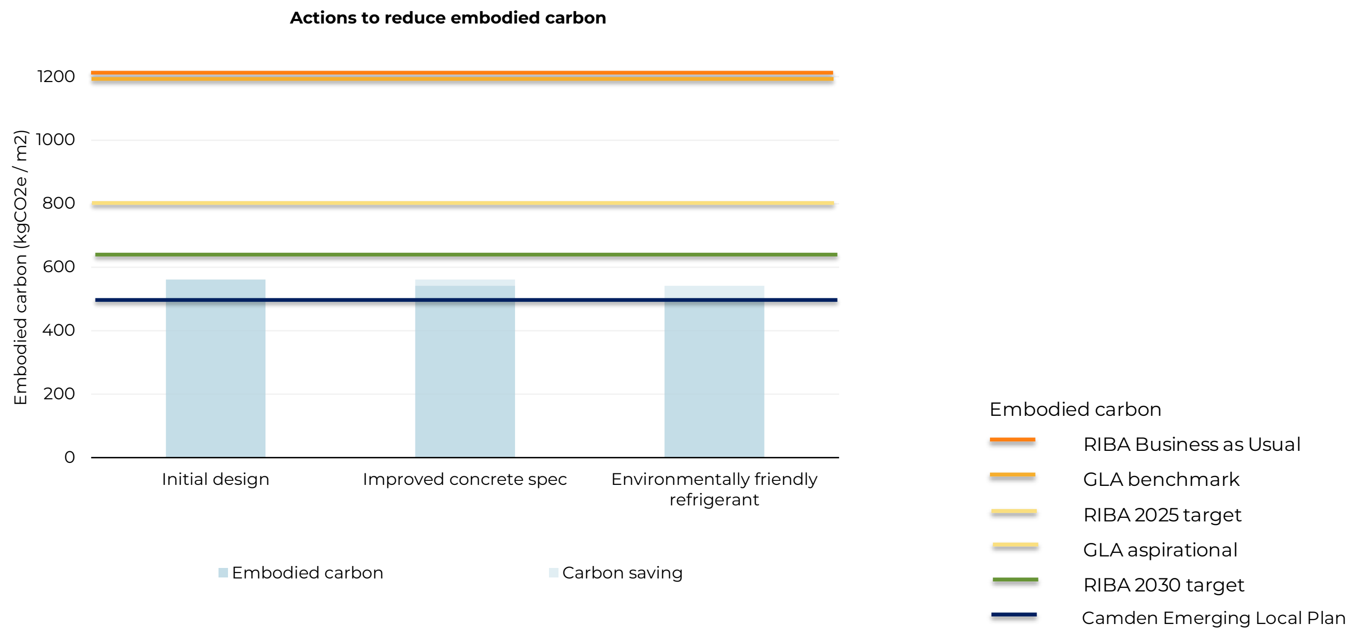


Figure 7. Actions taken to reduce embodied carbon emissions for Maresfield Gardens and comparison against industry and emerging policy benchmarks.

6 Conclusions

The whole life carbon emissions of three design scenarios were evaluated for the application site at 46 Maresfield Gardens in Hampstead, within the London Borough of Camden.

In terms of embodied carbon, the lowest embodied carbon was to retain the existing building as is. An energy efficient new-build scheme for the site would have the lowest operational carbon.

Further to this, the proposed development which entails demolition and new-build was found to meet currently and emerging policy benchmarks which indicates that the site has the potential to be developed in a way that has embodied carbon emissions which are within acceptable limits.

When reviewing embodied carbon impacts alone, the minor upgrades to the existing building as well as the refurbishment and extension scenario were found to outperform the demolition and new-build scenario. However, in terms of whole life carbon, the demolition and new-build scenario was found to result in lower overall carbon impacts due to lower operational carbon emissions achievable by the new-build scheme throughout its lifetime.

The demolition and new-build scenario will be beneficial in terms of carbon after 24 years compared to the refurbishment and extension scenario, which is well within the 60-year timeframe recommended by industry's guidance for use in whole life carbon assessments. It would also be beneficial in terms of carbon after 7 years when compared against the existing building with minor refurbishment.

Table 7. Carbon emissions by module in $kgCO2_e/m^2$ for each design scenario.

Emissions by module	A1-A3	A4	A5	B1	B2-B3	B4	B6	B7	C1	C2	C3	C4	Totals
Existing building	55	9	5	-	7	130	3,401	16	-	3	-	4	**3,626**
Refurb and extension	52	55	94	12	4	92	974	16	0	6	0	6	**1,313**
Demolition and new-build	133	77	146	12	7	100	529	16	6	12	0	7	**1,045**

Appendix A – Modelling inputs

Table 8. Material specifications defaults for UK projects, based on RICS guidance.

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 extrusions, 35% Recycled Content
Plasterboard	Partitioning/Ceilings	Min. 60% Recycled Content

Table 9. Refrigerant leakage rates based on CIBSE TM65 used to calculate module B1 and C1 emissions.

Product	Annual leakage rate	End of life recovery rate
VRF systems where a large amount of refrigerant pipework is installed and filled on site.	6%	97%

Table 10. Transport distances in line with RICS guidance.

Transport	km by road	km by sea
Locally manufactured e.g. concrete, aggregate	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 11. Lifespan in line with RICS guidance.

Building part	Building element	Expected lifespan
Roof	Roof covering	30
Superstructure	Internal partitions and linings	30
Finishes	Wall finishes: Render/Paint	30/10
	Floor finishes: Raised Access Floor/Finish layers	30/10
	Ceiling finishes: Substrate/paint	20/10
FF&E	Furniture and fittings	10
Services/MEP	Heat source	20
	Space heating/ air treatment	20
	Ductwork	20
	Electrical installations	30
	Lighting fittings	15
	Communications installations/ controls	15
	Water and disposal installations	25
	Sanitaryware	20
	Lift and conveyor installations	20
Façade	Opaque modular cladding, e.g. rainscreen, timber panels	30
	Glazed cladding/ curtain walling	35
	Windows and external doors	30

Appendix B – Detailed results

Table 12. Detailed results for the existing building with minor refurbishment to internals and installation of new gas boiler.

Code	Category	A1-A3	A4	A5	B2-B3	B4	B6	B7	C2	C4	Totals
	Water Use							2,304			2,304
2.1	Frame		47	8		56					111
3	Finishes		151	21		385					557
3.1	Wall finishes	805	90	102		1,561			61	2	2,620
3.3	Ceiling finishes	505	190	44		854			105	10	1,709
4	FF&E	1,183	109	142		3,224			63	0	4,721
4.1	General FF&E	4,234	212	251		10,049			153	4	14,903
4.2	Kitchen equipment	-469	54	-29		-804			6	35	-1,206
5.1	Public Health		139	26	572	230					967
5.1.1	Sanitaryware	395	157	46		79			22	0	699
5.2	Heating, Ventilation and Cooling (HVAC)	437	34	39	133	2,699			23	0	3,365
5.2.4	Ventilation air terminals, ductwork and ancillaries, control dampers, attenuation, fire safety related to ventilation equipment	1	0	0		3			0	0	4
5.3	Electrical installations	789	57	106	251	375			50	0	1,628
	Totals ($kgCO_2e$)	**7,880**	**1,241**	**757**	**956**	**18,709**	**489,720**	**2,304**	**482**	**51**	**522,101**
	Totals $kgCO_2e$ / m^2	**55**	**9**	**5**	**7**	**130**	**3,401**	**16**	**3**	**0**	**3,626**

Table 13. Detailed results for part demolition, major refurbishment and extension scenario.

Code	**Category**	**A1-A3**	**A4**	**A5**	**B1**	**B2-B3**	**B4**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**Totals**
	Operational							424,838						424,838
	Water Use								6,872					6,872
0.1	Treatment and demolition works; Facilitating works		1,360	7,694										9,055
0.1.1.2	Demolition works		1,269	2,388										3,657
0.1.2.3	Specialist groundworks	0												0
1	Sub-structure	2,644	2,835	17,970							1		0	23,451
1.1	Foundations and piling	13,028	4,318	3,896	-1		55				759		102	22,157
1.2.1	Lowest slab	6,200	736	991							142		31	8,101
2.1	Frame	-23,727	1,430	-3,245			41				24		552	-24,927
2.3	Roof	1,216	1,334	1,330			398				51		120	4,448
2.5	External envelope including roof finishes	-1,859	1,260	249			1,894				2		37	1,583
2.5.1	External - opaque envelope	13,795	1,415	559			2,197				1,292		124	19,381
2.6.1	Windows - vertical	996	1,150	54			2,385				5		180	4,770
2.7	Internal walls	802	136	94							116		0	1,148
3	Finishes	2,067	417	302			1,052			42	12	2	126	4,020
3.1	Wall finishes	1,429	487	295			3,001				10		12	5,234
3.2.3	Floor finishes	115	48	24			520				1		0	707
3.3	Ceiling finishes	-23	116	28			457				4		14	596
4	FF&E		75	12			261							348
4.1	General FF&E	452	15	23			2,969				2		0	3,462
5.1	Public Health		226	3,188			6,655							10,070
5.1.1	Sanitaryware	1,262	86	119			1,927				77		0	3,471
5.2	Heating, Ventilation and Cooling (HVAC)	4,159	388	397	5,033	1,868	16,489			168	318		1,462	30,282
8.1	Roads, paths, pavings, surfaces; Fencing, railings, walls; External fixtures		4,864	4,720										9,585
	Totals ($kgCO_2e$)	**22,555**	**23,968**	**41,090**	**5,031**	**1,868**	**40,300**	**424,838**	**6,872**	**210**	**2,815**	**2**	**2,760**	**572,309**
	Totals $kgCO_2e / m^2$	**52**	**55**	**94**	**12**	**4**	**92**	**974**	**16**	**0**	**6**	**0**	**6**	**1,313**

Table 14. Detailed results for the demolition and new-build scenario.

Code	Category	A1-A3	A4	A5	B1	B2-B3	B4	B6	B7	C1	C2	C3	C4	Totals
	Operational							230,731						230,731
	Water Use								6,872					6,872
0.1	Treatment and demolition works; Facilitating works		2,026	9,632										11,658
0.1.1.2	Demolition works		2,532	4,776						2,476				9,784
0.1.2.3	Specialist groundworks	1												1
1	Sub-structure	3,944	2,912	26,826							1		0	33,684
1.1	Foundations and piling	19,456	4,980	5,819	-2		82				1,135		153	31,623
1.2.1	Lowest slab	9,782	1,138	1,580			-2				235		108	12,840
2.1	Frame	-3,289	2,242	2,161			61				1,042		228	2,446
2.2	Upper floors			0										0
2.3	Roof	-2,186	1,641	1,661			395				35		178	1,724
2.5	External envelope including roof finishes	-2,894	1,688	338			2,072				2		54	1,261
2.5.1	External - opaque envelope	19,703	2,095	817			3,310				1,915		184	28,023
2.6.1	Windows - vertical	1,532	1,781	83			3,681				8		277	7,363
2.6.3	External doors	-3,753	11	-548			-4,221				2		67	-8,442
2.7	Internal walls	1,195	199	140							173		0	1,706
3	Finishes	3,081	455	437			1,165			62	18	2	188	5,409
3.1	Wall finishes	1,364	451	282			2,892				9		2	5,000
3.2.3	Floor finishes	-307	119	-20			788				52		9	640
3.3	Ceiling finishes	-35	178	42			688				6		21	901
4	FF&E	914	201	39			1,844				97		0	3,095
4.1	General FF&E	523	25	34			3,164				11		0	3,757
4.2	Kitchen equipment	-469	54	-29			-804				6		35	-1,206
5.1	Public Health		760	3,219			6,814							10,793
5.1.1	Sanitaryware	2,095	290	210			2,299				123		0	5,017
5.2	Heating, Ventilation and Cooling (HVAC)	4,136	398	398	5,033	2,225	16,171			168	319		1,413	30,259
5.2.4	Ventilation air terminals, ductwork and ancillaries	534	37	0			1,900				23		0	2,494
5.3	Electrical installations	2,389	174	320		760	1,135				152		0	4,930
8.1	Roads, paths, pavings, surfaces; Fencing, railings, walls; External fixtures		4,864	4,720										9,585
8.3	External drainage; External services; Minor building works		2,370	709										3,078
8.3.2	External services	151	12	16			270				8		0	457
	Totals ($kgCO_2e$)	**57,867**	**33,631**	**63,662**	**5,031**	**2,985**	**43,704**	**230,731**	**6,872**	**2,706**	**5,371**	**2**	**2,921**	**455,483**
	Totals $kgCO_2e / m^2$	**133**	**77**	**146**	**12**	**7**	**100**	**529**	**16**	**6**	**12**	**0**	**7**	**1,045**

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