

Whole Life Carbon Assessment

138-144 Friar Street

For National Pub Portfolio Limited

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ecolytik

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1 Executive Summary

This Whole Life Carbon assessment has been prepared by Ecolytik for the proposed scheme at 138-144 Friar Street, within the jurisdiction of Reading Borough Council (RBC).

Guidance available from Royal Institute of Chartered Surveyors (RICS) Professional Statement (PS), published in 2023, the European standard EN 15978, Low Energy Transformation Initiative's (LETI) Embodied Carbon Primer (2020), Royal Institute of British Architects' (RIBA) Climate Change Guide (2021), and UK's Net Zero Carbon Building Standard (NZCBS), published in 2026, and BREEAM New Construction Version 7 (v7) were considered for the assessment.

The study period was set to 60 years. Due to the early stage of the project, an overall Uncertainty Factor (UF) of 26% has been applied to the results, in line with RICS 2023 guidance for uncertainty associated with the design phase (15%), material quantity (4%) and carbon data quality (7%). As the project progresses to detailed design and construction stages, these factors would reduce, and the associated findings would be revised accordingly. Two sets of results were generated considering a scenario without decarbonisation of the grid, as well as a decarbonisation scenario.

The report aims to assess Whole Life Carbon (WLC) defined as those carbon emissions resulting from the construction and the use of a building over its entire life, including its demolition and disposal. This assessment captures the operational carbon emissions from both regulated and unregulated energy use. The study also includes an assessment of the potential carbon emission 'benefits' from the reuse or recycling of components after the end of the development's useful life. The assessment results form a baseline against which future designs can be assessed.

The main body of the report focuses on the evaluation and prediction of WLC emissions. Assessment and review of impacts across other environmental indicators are presented in Appendix C, in line with BREEAM v7 requirements.

1.1 Results

The initial analysis at planning stage indicates that the results would be above the most ambitious

industry benchmarks for both the non-decarbonised and the decarbonised scenarios. This is expected, given the high degree of uncertainty during early project stages. When reducing the uncertainty factors, then the results were found to be consistent with various available industry benchmarks. Figure 1 illustrates this for the non-decarbonised scenario. When disregarding uncertainty factors, the scheme is predicted to achieve an embodied carbon footprint of circa 800 kgCO₂e/m² for the substructure, superstructure and finishes as per emerging policy CC2 of RBC's Local Plan Draft Partial Update.

Upfront carbon (including product and construction stage carbon emissions) was found to be in region of 811 kgCO₂e/m² excluding sequestration, while sequestration benefits were found to be circa 108 kgCO₂e/m² for the proposed development.

In-use carbon (associated with maintenance, repair, refrigerant fugitive emissions) was found to be circa 612 kgCO₂e/m² for the non-decarbonised scenario and approximately 306 kgCO₂e/m² for the decarbonised scenario.

Operational carbon (energy and water use) was estimated to be circa 800 kgCO₂e/m² for the non-decarbonised scenario and 200 kgCO₂e/m² for the decarbonised scenario.

End-of-life carbon (covering demolition, waste processing and disposal) was predicted to be 220 kgCO₂e/m² and 175 kgCO₂e/m² for the non-decarbonised and decarbonised scenarios respectively.

Embodied carbon (all emissions aside from operational energy and water) was calculated to be in the region of 1,100-1,500 kgCO₂e/m² depending on the decarbonisation scenario.

The predicted carbon benefits beyond the boundary were found to range between 19-38 kgCO₂e/m² depending on the grid carbon factors.

Figure 2 shows the predicted distribution of carbon emissions for each life cycle module, for the non-decarbonised scenario. Detailed numerical results for both the non-decarbonised and decarbonised scenarios are presented in section 4 and Appendix B of this report.

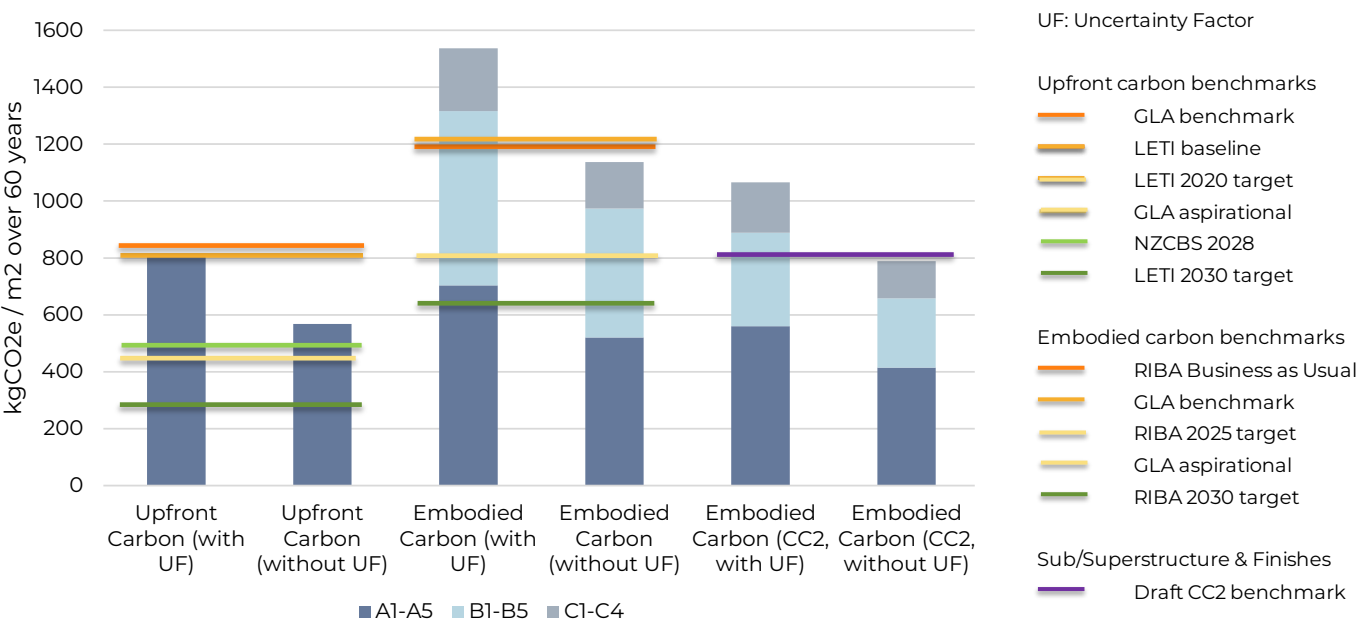


Figure 1. Upfront and embodied carbon comparison of 138-144 Friar Street with industry benchmarks (non-decarbonised scenario).

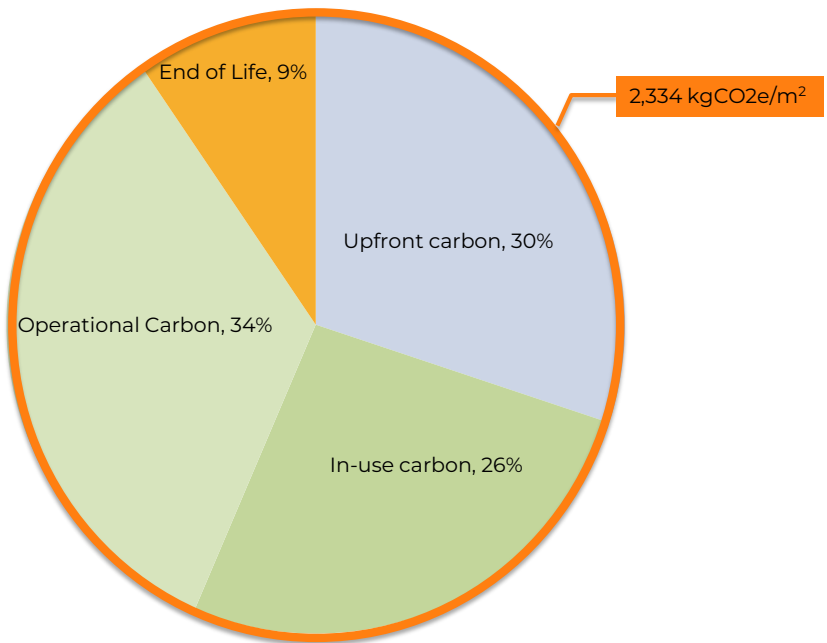


Figure 2. Distribution of whole life carbon emissions for 138-144 Friar Street (non-decarbonised scenario with inclusion of uncertainty factors at RIBA Stage 2).

1.2 Potential improvements

Potential opportunities to reduce embodied carbon emissions were also identified in this report and included the use of cement replacement in the concrete and durable floor finishes.

Early-stage calculations typically include more conservative estimates, and it is envisaged that with further input from structural and M&E engineers as the design progresses post-planning, further efficiencies may be achievable. Reducing uncertainty factors in the assessment together with establishing more accurate material quantities are likely to result in notable refinements to the predicted carbon emissions.

The assessment was carried out using industry-average data to form a conservative baseline while as the project progresses, specific Environmental Product Declarations (EPDs) could be used. It is anticipated that the use of EPDs for most key materials of the scheme could provide further reductions in the carbon emissions estimates.

All considerations above are currently predicted to yield notable embodied and upfront carbon savings, as illustrated in Figure 3 and Figure 4 respectively for the non-decarbonised scenario of modelling. This would bring the scheme closer to more ambitious industry benchmarks.

When considering the potential decarbonisation of the grid and the fact that the scheme is proposed to be fully electric, whole life carbon emissions are likely to reduce further.

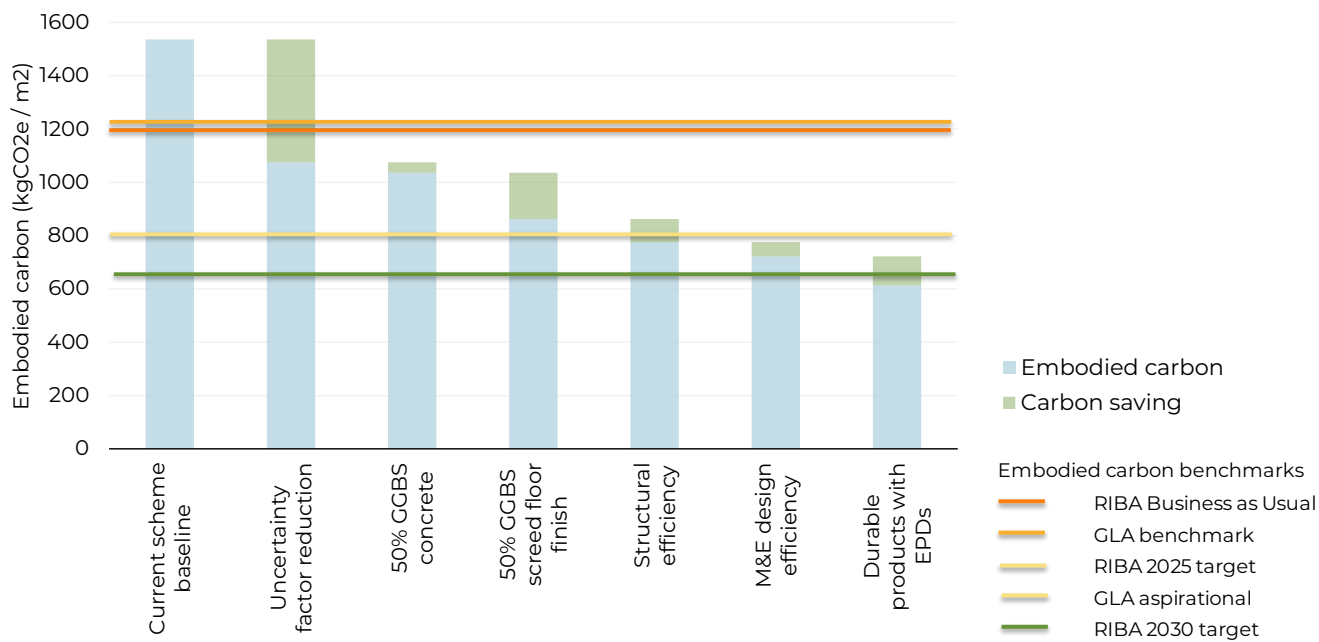


Figure 3. Potential embodied carbon reduction opportunities for 138-144 Friar Street (non-decarbonised scenario).

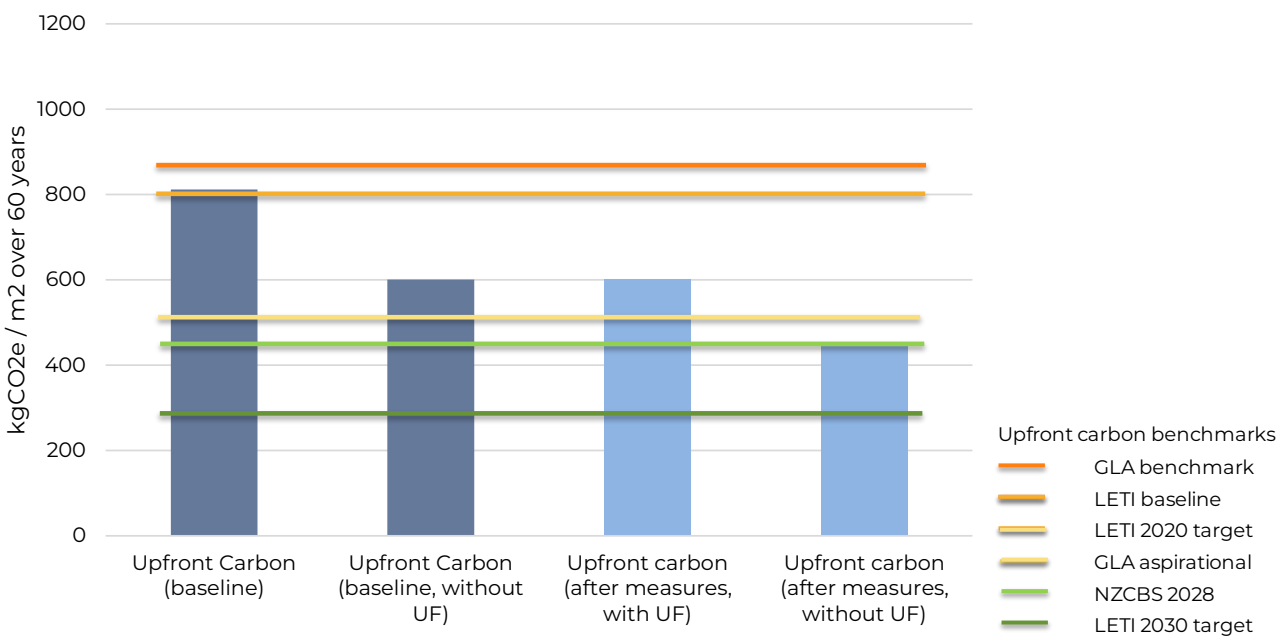


Figure 4. Upfront carbon of the current scheme and after potential improvements (non-decarbonised scenario).

2 Introduction

2.1 Site

The site is situated in the heart of Reading Town Centre, adjacent to the key junction of Friar Street and Queen Victoria Street (QVS), approximately a 3-minute walk (circa 250m) from Reading Railway Station.

The site is located adjacent to Queen Victoria Street – Phase 1 (QVS1), which has consent for hotel and leisure use and is currently under refurbishment. These proposals relate to Queen Victoria Street – Phase 2 and are linked to the expansion of the QVS1 application, aiming to further the shared vision of Reading Borough Council and local stakeholders.

A previous application for hotel use on this site was approved (planning ref: PL/22/1235); however, following review the hotel proposal was not considered viable.

The current application is for the phased redevelopment of the site involving the demolition of Nos. 138–141 and 142–143 Friar Street, partial demolition of No. 144 Friar Street, and erection of a basement and 6-storey building to provide co-living residential accommodation (purpose-built shared living accommodation – Sui Generis use class), together with the partial retention of the former Bugle Public House as a standalone Class E commercial unit.

The indicative site location is shown in Figure 5.

2.2 Report aims

This report sets out the Whole Life Carbon (WLC) assessment for 138-144 Friar Street including:

- Calculations of whole life carbon accounting for upfront carbon, in-use embodied carbon, end of life carbon and operational utility (energy and water) carbon.
- Comparison of results with relevant industry benchmarks.
- Identifying opportunities to reduce whole life carbon emissions.



Figure 5. Indicative site location of 138-144 Friar Street (source: Google Maps, accessed: July 2026).

2.3 Building Regulations

There is no Building Regulations Approved Document on Whole Life Carbon emissions.

2.4 Planning policy review

A review of the applicable adopted policies for the proposed development has been undertaken, including RBC’s Local Plan (Draft Partial Update, 2025), as well as RBC’s Sustainable Design and Construction Supplementary Planning Document (SPD), published in 2019.

Emerging Policy CC2 of the Local Plan Draft Partial Update stipulates the following:

“The demolition of an existing building should be accompanied by a full justification for demolition and demonstrate how 95% of all construction waste will be diverted away from landfill. For non-listed buildings, demolition will only be acceptable where:

- *The building is in such a poor state that it is not practical or viable to refurbish or re-use;*
- *Such refurbishment or re-use would result in a similar amount or a greater amount of embodied carbon generation; or*
- *Such refurbishment or re-use would result in a building with poor thermal efficiency resulting in a greater lifetime carbon emissions than would arise from a re-build.*

All applications for new-build commercial floorspace of 5000m² or more must include an embodied carbon assessment. This assessment must demonstrate that a score of less than 800kg/m² of carbon can be achieved within the development for the substructure, superstructure and finishes.”

Furthermore, paragraph 5.2.15 of the Local Plan Draft Partial Update states:

“There is undoubted physical capacity within the centre to incorporate a significant level of new development, by efficient use of underused land through carefully developing at higher densities. This represents the most significant opportunity to accommodate new development within Reading....”

Given the aforementioned fact, and the fact that 1-15 Queen Victoria Street and 145-148 Friar Street (PL/22/1232), together with 138-144 Friar Street (PL/22/1235), already benefit from recent planning permissions establishing the principle of development (involving demolition and densification), it is considered that detailed justifications for demolition of the existing buildings at 138-144 Friar Street is not deemed required as part of the current application for the site. Further to this, the principle and scale of the development at 138-144 Friar Street is fairly similar to the existing planning consent from an environmental perspective.

In response to emerging policy CC2, Ecolytik has been appointed to prepare a Whole Life Carbon Assessment (with CIBSE TM54 Energy Assessment) in line with the latest RICS 2023 guidance, to inform the design and future decision making for improving the sustainability credentials of the proposed scheme. This is considered proportionate given Reading’s potential development needs identified within the Local Plan Draft Partial Update, planning history, similarities in scale and proportion of development, etc and is a positive response to emerging policy CC2.

In line with emerging policy CC2, the proposed development at 138-144 Friar Street will also aim to achieve the target of 95% of all construction waste to be diverted from landfill. The client and design team have also aimed to meet the embodied carbon target of 800 kgCO₂e/m² for the substructure, superstructure and finishes, albeit the scale of the proposal does not go above the 5,000m² floor space threshold.

READING BOROUGH
LOCAL PLAN

Adopted November 2019
Submission Draft Partial Update May 2025

Reading
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2.5 Industry guidance

There are several guidance documents on Whole Life Carbon in the construction industry:

- The Royal Institute of Chartered Surveyors' (RICS) Professional Statements (PS), published in 2017 and 2023.
- Low Energy Transformation Initiative's (LETI) Embodied Carbon Primer (2020).
- Royal Institute of British Architects' (RIBA) Climate Change Guide (2021).
- Many Local Authorities have recently produced policies and guidance on WLC. Perhaps among the first and most notable ones include the Greater London Authority's (GLA) guidance with benchmarks in 2022.
- The most recent industry wide initiative on WLC is UK's Net Zero Carbon Building Standard (NZCBS), published in 2026. This document also includes benchmarks.

Other standards and guidelines produced both nationally and internationally include:

- ISO 14040: 2006 + A1: 2020, Environmental management, Life cycle assessment, Principles and framework.
- ISO 14044: 2006 + A2: 2020, Environmental management, Life cycle assessment Requirements and guidelines.

EN 15978:2011, Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method. An international standard detailing how to model and report a Life Cycle assessment for construction projects, follows the modular approach of reporting impacts where they occur in the life cycle module.



3 Methodology

The methodology followed in calculating the embodied carbon emissions is aligned with the RICS professional statement (PS) 2023 for undertaking detailed carbon assessments. The RICS Whole life Carbon Assessment for the Built Environment follows the European standard EN 15978. Conservative assumptions in the modelling have generally been prioritised at planning stage.

The assessment includes 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-B8, 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.

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 – B8] 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 1 shows the life-cycle stages that were considered for the assessment. Table 2 illustrates the life cycle stages and terms used to describe the various types of emissions. Embodied carbon for example only considers lifecycle stages A1 to B5 and C1 to C4.

Table 1. Life cycle stages considered in the whole life carbon assessment.

Product Stage			Construction Process Stage			Use Stage								End-of-Life Stage				Benefits beyond boundary	
Pre-construction stage	Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	User carbon	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse, recycling, energy recovery	Exported utilities
A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D1	D2
x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	✓	✓

Table 2. Definitions of types of carbon emissions.

Product Stage			Construction Process Stage			Use Stage								End-of-Life Stage				Benefits beyond boundary	
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D1	D2	
Cradle to gate																			
Upfront / Cradle to site																			
Embodied carbon (excludes B6, B7, B8)										End of Life									
					Use stage carbon														
										Operational		User							
Whole Life Carbon / Cradle to grave																			
																	Beyond lifecycle		

3.2 Building elements

The assessment considers the elements presented in Table 3.

Sequestered (biogenic) carbon, in particular from the use of timber products, is reported separately. It is typically excluded from upfront carbon (Modules A1-A5) but included in embodied carbon (Modules A-C excluding B6-B8).

Embodied carbon is challenging to calculate for Mechanical and Electrical (M&E) services systems due to a lack of detailed available data and Environmental Product Declarations (EPD). Where manufacturer specific data is not available, figures for Embodied Carbon have been taken from the closest matching system within the software's database and considering the latest guidance from the Chartered Institution of Building Services (CIBSE) Technical Memorandum 65 (CIBSE TM65), published in 2021.

3.3 Software

The software used for the assessment is eToolLCD, which follows BS EN 15978, is IMPACT-compliant and BRE certified.

The use of Environmental Products Declaration (EPD) data has been considered for the assessment at RIBA Stage 2 but exact product specifications are not known at this early stage. Where detailed specification of products and materials were yet to be fully determined. The use of generic industry data is considered to be appropriate and would represent a more conservative scenario in the absence of detailed product selections at an early design stage.

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 options. 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 and industry bodies.

Table 3. Building elements considered in the assessment as per RICS standard.

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

3.4 Assessment information

The assessment is based on the planning stage drawings by Falconer Chester Hall Architects and a preliminary structural scheme by Bellamy Wallace Partnership.

Material quantity information has been derived from the drawings and where information is not available, conservative estimations have been made.

For building services systems, information obtained from M&E consultants Innovo and heat pump supplier Mitsubishi were used to inform the assessment.

3.4.1 Construction

The construction elements considered in the assessment is shown in Table 4.

3.4.2 Operation

Operational carbon emissions can arise from water (module B7) and energy use (module B6) on site.

There are two types of Operational Carbon emissions from energy use on site (module B6). Regulated carbon emissions arise from the specification of controlled, fixed building services and fittings such as heating, cooling systems (if any), hot water, ventilation, fans, pumps and lighting for heated spaces.

Unregulated carbon emissions result from systems or processes that are not ‘controlled’, i.e. energy consumption from systems or activities in the building on which the Building Regulations do not impose a requirement. For example, this may include energy use arising from small power plug-in equipment, kitchen equipment, IT equipment, lifts, printers, photocopiers, and other appliances.

An energy assessment with CIBSE TM54 methodology was carried out at planning stage and the predicted energy for each end-use were included in the WLC modelling. Please refer to the accompanying TM54 Energy Assessment report for further information.

Table 4. Key assumptions used in the assessment.

Element	Planning Stage Outline Assumptions
Substructure	Circa 3,200m ³ of excavation, 1,700m of 450mm diameter concrete bored piles, circa 50m ³ of pile caps, and 230m ³ of concrete for the raft below basement. Ground floor slab 300mm, 150mm rigid insulation for heat loss floors. Allowances for waterproofing, reinforcement of concrete, membranes, perimeter insulation, formwork, etc were included in the modelling using typical rules of thumb.
Upper floors and roofs	Upper floors included 225mm concrete slabs with reinforcement. 150m ³ of concrete for columns and 360m ³ for core walls. Stairs estimated to include circa 21m ³ of concrete. Allowances for handrails, formworks, etc were included in the modelling where required. Flat concrete roof 275mm thick. Reinforcement allowances include 200kg/m ³ for all concrete elements except columns where 300 kg/m ³ was modelled.
External walls	Plasterboard internally, metal studs, insulation and outer brick construction for the front elevation and render to the rear elevations was included in the analysis.
Internal walls	Steel frame with plasterboard both sides, insulation (where required, e.g. walls to corridors). Internal partition walls within co-living units modelled with Oriented Strand Board (OSB) support.
Windows	Double-glazed hybrid frame windows modelled throughout the scheme.
External works	Small area on Fife Court leading to the ground floor substation was modelled as hard landscaping with asphalt (hot mix) with 4% recycled content, as worst-case approach. Soft landscaping was included for the courtyard on the western side of the proposed building.
M&E	Centralised Air Source Heat Pumps (ASHP) with R32 and R454C refrigerants were include in the modelling. Mechanical Ventilation with Heat Recovery (MVHR) was modelled for all co-living units and habitable areas on the basement and ground floor of the development. Allowances were included for ancillary plant comprising water storage tanks, cabling, pipework distribution, cable trays, radiators, pumps, ASHP screening, etc. PV array size 25.6 kWp on the roof. The embodied carbon impact of PV was based on best practice performance of 1,000 kgCO ₂ e / kWp set out in UK’s NZCBS.
Energy and water use	Preliminary TM54 calculations carried out for all potential energy uses on site covering regulated, unregulated, external lighting, lifts, etc. Water use was derived on the basis that all co-living units will have efficient fittings installed to achieve the Part G(2) target of 110 litres per person per day.

4 Results

4.1 Baseline assessment

The distribution of whole life carbon emissions by module is shown in Figure 6. It can be seen that upfront carbon (module A) represents circa 30% of the lifecycle emissions, in use carbon (module B) about 60% (with 34% being operational carbon of modules B6 and B7), while end-of-life carbon (module C) accounts for approximately 9% of the lifecycle emissions.

These findings illustrate the importance of resource efficiency and selection of environmentally friendly materials during construction as upfront carbon can claim the highest proportion of emissions.

End-of-life emissions can be mitigated as far as possible by adopting circular economy design techniques that could potentially enable durable materials (such as bricks) to be reused at the end of the project’s useful life.

Figure 7 shows the comparison of this baseline design for the scheme against various industry benchmarks. The scheme is predicted to be within recognised industry benchmarks once the uncertainty associated with early-stage assessments is reduced. It is recommended the assessment is updated during the design and construction stages to reflect as closely as possible the proposed scheme.

The tables on the following pages summarise the results for both the non-decarbonised (Table 5) and decarbonised modelling scenarios (Table 6).

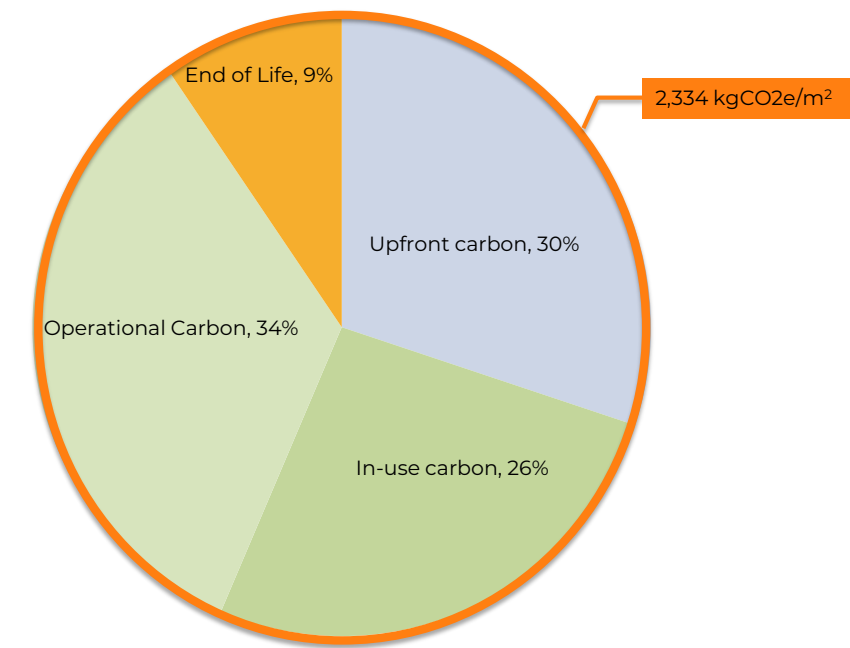


Figure 6. Distribution of whole life carbon emissions for 138-144 Friar Street (non-decarbonised scenario, with uncertainty factors included at RIBA Stage 2).

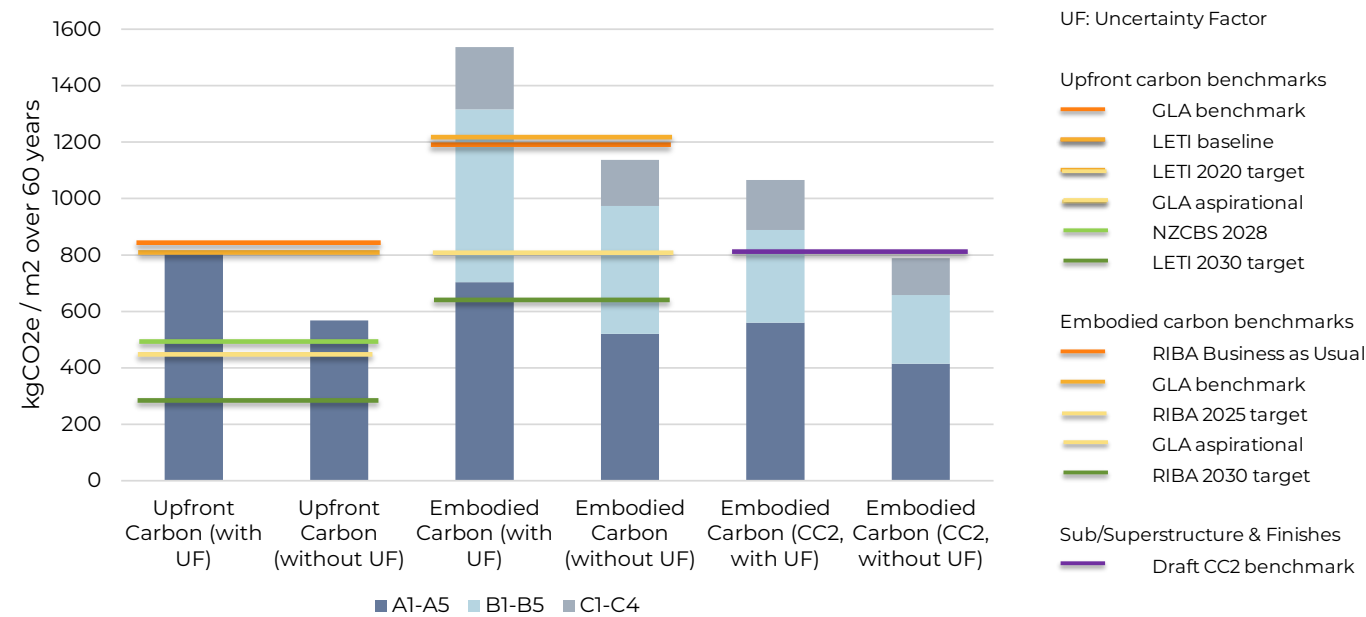


Figure 7. Upfront and embodied carbon comparison of 138-144 Friar Street with industry benchmarks (non-decarbonised scenario).

Table 5. Results summary for the non-decarbonised modelling scenario with uncertainty factors included at RIBA Stage 2.

Building element category		Upfront embodied carbon excl. sequestration [A1-A5]	Upfront embodied carbon excl. sequestration [A1-A5]	Upfront embodied carbon sequestered [A1-A5]	Upfront embodied carbon sequestered [A1-A5]	Total operational carbon [B6, B7, B8]	Total operational carbon [B6, B7, B8]	Whole life embodied carbon [A-C] excl. [B6, B7, B8]	Whole life embodied carbon [A-C] excl. [B6, B7, B8]	Whole life carbon [A-C]	Whole life carbon [A-C]
		kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²
	Asset level emissions	-	-	-	-	3,930,518	798	81,942	17	4,012,461	814
0.1	Demolition works	114,542	23	-	-	-	-	-	-	-	-
0.2	Facilitating works	23,729	5	-8	-0	-	-	23,729	5	23,729	5
1.0	Substructure	980,715	199	-23,997	-5	-	-	1,088,892	221	1,088,892	221
2.0	Superstructure - Structural elements	1,159,610	235	-188,964	-38	-	-	1,418,843	288	1,418,843	288
2.0	Superstructure - Building envelope	669,615	136	-67,809	-14	-	-	960,879	195	960,879	195
2.0	Superstructure - Internal elements	50,220	10	-89,889	-18	-	-	81,250	16	81,250	16
3.0	Finishes	321,035	65	-52,014	-11	-	-	1,703,626	346	1,703,626	346
4.0	Fittings, furnishings and equipment (FF&E)	149,226	30	-108,779	-22	-	-	430,236	87	430,236	87
5.0	Services (MEP)	494,736	100	-832	-0	-	-	1,576,501	320	1,576,501	320
6.0	Pre-fabricated buildings and units	-	-	-	-	-	-	-	-	-	-
7.0	Works to existing buildings	-	-	-	-	-	-	-	-	-	-
Sub-total		3,963,428	804	-532,293	-108	3,930,518	798	7,365,899	1,495	11,296,417	2,292
8.0	External works associated with the project (within boundary)	35,206	7	-47	-0	-	-	89,668	18	89,668	18
8.0	External works associated with the project (outside of boundary)	-	-	-	-	-	-	-	-	-	-
Total		3,998,634	811	-532,340	-108	3,930,518	798	7,455,567	1,513	11,386,085	2,310

Table 6. Results summary for the decarbonised modelling scenario with uncertainty factors included at RIBA Stage 2.

Building element category		Upfront embodied carbon excl. sequestration [A1-A5]	Upfront embodied carbon excl. sequestration [A1-A5]	Upfront embodied carbon sequestered [A1-A5]	Upfront embodied carbon sequestered [A1-A5]	Total operational carbon [B6, B7, B8]	Total operational carbon [B6, B7, B8]	Whole life embodied carbon [A-C] excl. [B6, B7, B8]	Whole life embodied carbon [A-C] excl. [B6, B7, B8]	Whole life carbon [A-C]	Whole life carbon [A-C]
		kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²	kgCO ₂ e	kgCO ₂ e/m ²
	Asset level emissions	-	-	-	-	1,005,681	204	40,971	8	1,046,652	212
0.1	Demolition works	114,542	23	-	-	-	-	-	-	-	-
0.2	Facilitating works	23,729	5	-8	-0	-	-	23,729	5	23,729	5
1.0	Substructure	980,715	199	-23,997	-5	-	-	1,038,859	211	1,038,859	211
2.0	Superstructure - Structural elements	1,159,610	235	-188,964	-38	-	-	1,295,927	263	1,295,927	263
2.0	Superstructure - Building envelope	669,615	136	-67,809	-14	-	-	819,833	166	819,833	166
2.0	Superstructure - Internal elements	50,220	10	-89,889	-18	-	-	66,035	13	66,035	13
3.0	Finishes	321,035	65	-52,014	-11	-	-	1,013,780	206	1,013,780	206
4.0	Fittings, furnishings and equipment (FF&E)	149,226	30	-108,779	-22	-	-	290,331	59	290,331	59
5.0	Services (MEP)	494,736	100	-832	-0	-	-	1,070,514	217	1,070,514	217
6.0	Pre-fabricated buildings and units	-	-	-	-	-	-	-	-	-	-
7.0	Works to existing buildings	-	-	-	-	-	-	-	-	-	-
Sub-total		3,963,428	804	-532,293	-108	1,005,681	204	5,659,980	1,149	6,665,661	1,353
8.0	External works associated with the project (within boundary)	35,206	7	-47	-0	-	-	62,551	13	62,551	13
8.0	External works associated with the project (outside of boundary)	-	-	-	-	-	-	-	-	-	-
Total		3,998,634	811	-532,340	-108	1,005,681	204	5,722,530	1,161	6,728,212	1,365

4.2 Carbon hotspots

Initially, key carbon hotspots were identified through analysis of key categories as shown in Table 7. This indicates where most carbon emissions are expected to arise from, as well as the opportunities that should be explored to reduce embodied carbon.

The first one includes the structure of the building, including foundations, slabs and frame made of reinforced concrete.

The use of cement replacement should be explored to reduce impacts. The use of Ground Granulated Blast-furnace Slag (GGBS) or other supplementary cementitious materials (e.g. fly ash, limestone, ternary blend or calcined clay equivalents). However, it should be noted that curing times when high percentage of GGBS is used are typically higher.

Steel used to reinforce concrete was also found to claim a notable portion of the embodied carbon emissions. However, steel has very high recycling rates in the UK and there is limited potential to reduce the impact, aside from achieving structural efficiencies through detailed design post-planning.

Finishes were also found to claim a notable proportion of embodied carbon emissions. Floor finishes which may lead to frequent replacement over the lifecycle of the project should be avoided (e.g. LVT floor finishes are assumed to be replaced every 7 years in line with RICS guidance). Durable materials which do not require frequent maintenance should be prioritised.

Building services systems also tend to contribute to a notable extent in terms of embodied carbon emissions. This is due to the requirement to maintain and replace these systems over the 60-year study period, as well as from emissions associated with the refrigerants. The design to date has adopted refrigerants with relatively low Global Warming Potential (GWP), including R32 and R454C.

End of life impacts from certain materials can be mitigated through reuse schemes already available in the marketplace or could be recycled in line with expected recycling rates set out in current policies and industry guidance.

The following section of the report explores potential carbon savings that could be achieved by going beyond common practice specifications set out within RICS guidance and considering the carbon hotspots identified for the scheme.

Table 7. Life cycle emissions impacts by category (non-decarbonised scenario).

Category	Life cycle emissions (kgCO ₂ e / m ²)	Life cycle emissions (kgCO ₂ e/m ²)
Substructure	117	11%
Superstructure	393	38%
Finishes	260	25%
FF&E	64	6%
Services	206	20%
External works	8	1%

4.3 Carbon reduction opportunities

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. Certain material quantities may be more conservative during early project stages and are expected to be refined as the scheme progresses to construction.

Nevertheless, the assessment has indicated what the key carbon hotspots are likely to be. As the design progresses, the modelling can be refined to more accurately reflect the materials or products used which could deliver embodied carbon savings.

The following options are recommended for review to reduce embodied carbon emissions:

- Use of concrete with blast furnace slag or other cement replacements in the mix in proportions higher than those stipulated in RICS guidance for the substructure. Using 50% in this scheme (beyond the 25% assumed as standard UK practice based on RICS guidance) was found to provide approximately 30-40 kgCO₂e/m² embodied carbon savings.
- Use of durable floor finishes (such as screed with 50% cement replacement instead of LVT) could offer embodied carbon savings over 150 kgCO₂e/m².
- Improvements in structural efficiency would rely on input from structural engineers on the scheme and may result in lower material quantities relative to early-stage calculations. Refinements to required excavation, foundation design and depths could reduce material quantities and result in savings exceeding 80 kgCO₂e/m².
- Early-stage M&E quantities are based on rules of thumb to determine distribution runs, and the actual design is likely to be more efficient. Subject to M&E consultant input, initial estimates indicate that there are potentially over 50 kgCO₂e/m² of carbon savings that could be achieved from this building element category.
- The use environmentally friendly materials from suppliers with robust Environmental Product Declarations (EPD) is likely to offer further improvements to the results when

compared to industry averaged data used. It is difficult to currently estimate accurately the potential savings from the above opportunities, but previous project experience indicates that over 100 kgCO₂e/m² additional carbon savings could be possible.

The results indicate that with the adoption of more environmentally friendly construction techniques, the selection of durable materials from reputable suppliers that come with EPDs, as well as potential design efficiencies to be identified during the detailed design and construction stages of the project, the proposed development could approach closer to more ambitious industry benchmarks that the baseline scheme assessed at planning stage.

The measures above were found to provide a circa 30% reduction in embodied carbon emissions over a conservative baseline estimate, but are subject to detailed design and ongoing input from the wider team.

Applying a similar level of reduction to upfront carbon, the project could potentially achieve upfront carbon levels below 500 kgCO₂e/m² which would bring it closer to NZCBS upfront carbon limit of 450 kgCO₂e/m² (2028), as shown in Figure 9.

If it is of interest to the project team and client, it is recommended that this whole life carbon assessment be updated during subsequent project stages (detailed design and construction) to evaluate whether the scheme can achieve the more ambitious standards both from operational as well as from embodied carbon perspectives.

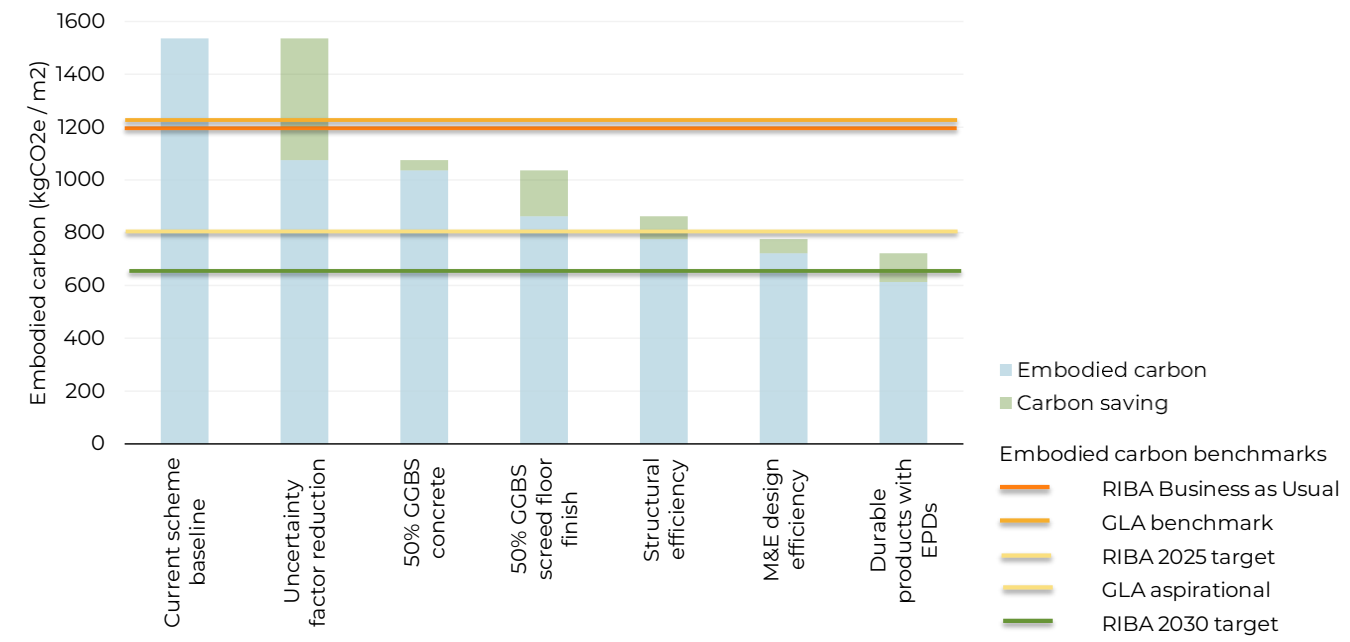


Figure 8. Potential embodied carbon reduction opportunities for 138-144 Friar Street (non-decarbonised scenario).

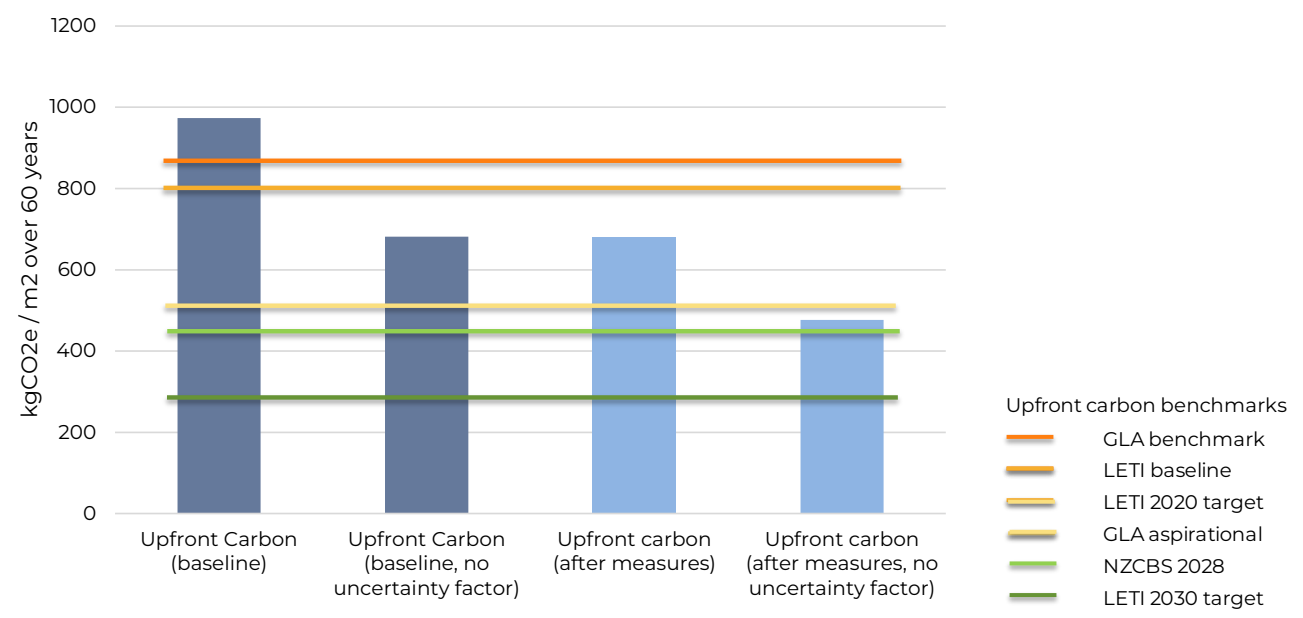


Figure 9. Upfront carbon of the current scheme and after potential improvements (non-decarbonised scenario).

5 Conclusions

This Whole Life Carbon (WLC) assessment has been undertaken for the proposed residential development at 138-144 Friar Street and to support informed design decision-making at an early stage. The assessment has been prepared in line with relevant industry guidance, including RICS, EN 15978 and emerging best practice, and considers both embodied and operational carbon emissions over a 60-year study period. As such, the results provide a baseline against which future design development and potential improvements can be measured.

The assessment has highlighted that embodied carbon represents the dominant contribution to whole life carbon emissions for the proposed scheme, reflecting the increasing importance of material selection and construction techniques in the context of low-operational-energy schemes.

The design approach adopted to date, including rationalised layouts and a focus on fabric-first principles, has supported a balanced whole life carbon outcome that can aligns with current and emerging industry benchmarks.

Key carbon hotspots have been identified across for the scheme, providing direction on where future efforts should be focused. The study has shown that there is meaningful potential to reduce embodied carbon through a combination of specification-led measures, such as increased use of cement replacement, reclaimed or recycled materials, and greater reliance on product specific EPDs, alongside further optimisation through detailed structural and services design.

Operational carbon emissions are anticipated to remain relatively low due to the high performance of the building fabric and the use of low-carbon building services, supported by on-site renewable energy generation.

Overall, the proposed development performs in line with current planning policy objectives and industry guidance. With continued design refinement and collaboration across the project team, there is a clear pathway for the scheme to further reduce its carbon impact and move closer to more ambitious targets set by initiatives such as RIBA 2030 and the Net Zero Carbon Building Standard. It is recommended that the Whole Life

Carbon assessment is updated at subsequent design stages to reflect increased design certainty and to support the delivery of a lower-carbon outcome.

Appendix A – Modelling assumptions

The following tables in this appendix include key assumptions taken from RICS 2023 PS. The information in this appendix is not exhaustive, and further information should be sought if required from RICS 2023 guidance.

Table 8. Material specifications assumptions.

Material	Details	Baseline specification representative of standard practice (UK)
Concrete, cast in situ (ready-mix concrete)	Piling and foundations	Reinforced concrete, C32/40, 25% cement replacement
	Vertical structural elements, e.g. columns, walls	Reinforced concrete, up to 20 storeys (in situ, C32/40, 25% cement replacement, excluding reinforcement)
	Vertical structural elements, e.g. columns, walls	Reinforced concrete, over 20 storeys (in situ, C40/50, 25% cement replacement)
	Horizontal structural elements, e.g. beams, slabs	Reinforced concrete (C32/40, 25% cement replacement)
	Facilitating/auxiliary works	Reinforced concrete (C16/20, 25% cement replacement)
	Backfill	Reinforced concrete (C8/10, 25% cement replacement)
Concrete, precast	Structural elements: beams, segments, slabs, etc. pours of <25m ³	Reinforced concrete (C40/50, 0% cement replacement)
	Structural elements: beams, segments, slabs, etc. pours of >25m ³	Reinforced concrete (C40/50, 25% cement replacement, excluding reinforcement)
	Cladding panels	C16/20, 0% cement replacement
Concrete, sprayed	Tunnel/shaft linings Curved surfaces: roof shells, domes, etc.	Fibre reinforced concrete, C32/40, 0% cement replacement)
Concrete, reinforcement	Reinforcement bars	UK CARES sector average (typically 96% recycled content in UK)
Steel	Sheet piling	Blended EAF/BOF
	Structural steel sections – rolled sections	Blended market rate[5] of 60% BOF/40% EAF production
	Structural steel sections – plate and closed sections	100% BOF production
	Studwork/support frames	Galvanised steel, 15% recycled content
	Galvanised profiled sheet	UK TATA ComFlor®
Masonry	Precast concrete blocks	Lightweight aerated autoclaved concrete (AAC, such as Aircrete) blocks for non-structural uses (600kg/m ³)
	Precast concrete blocks	Medium-density blocks for structural uses (1425kg/m ³)
	Brickwork	Generic UK clay brick, dry brick weight 2.13kg
Timber	Manufactured structural timber: cross-laminated timber (CLT), Glulam, laminated veneered lumber (LVL), etc.	Engineered wood, sustainably sourced
	Studwork (e.g. secondary members such as internal partitions)	Softwood, C16, sustainably sourced
	Framing (e.g. primary members such as joists)	Softwood, C24, sustainably sourced
	Formwork	Plywood, sustainably sourced
Aluminium	Sheet	Aluminium sheet, 31% recycled content
	Extruded profiles	Aluminium extrusions, 31% recycled content
Plasterboard	Partitioning/ceilings	FGD gypsum plasterboard (approximately 10% recycled content)

Material	Details	Baseline specification representative of standard practice (UK)	
Insulation	For floors and external walls	Mineral wool	
	For roof – polyisocyanurate (PIR)/ rigid polyurethane (PU)	Polyurethane (PU) rigid foam	
Aggregates/ granular material	Fill material	Aggregates and sand, general UK fill material, mixture of land won, marine, secondary and recycled, bulk, loose	
Glass	Glass: general, glazing, toughened, multi-layer safety, skylight, fibreglass, expanded glass	Relevant generic datasets	
Plastics	Plastics (various)	Relevant generic datasets	
Coatings	Paints: general, waterborne, solvent-borne	Relevant generic datasets	
	Intumescent coating for steel	Amotherm steel WB	
	Cementitious spray	Isolatek international product average	
Asphalt	For highway and pavement construction	Asphalt, 5% binder content	
Bitumen	For road construction, roofing, waterproofing and other applications	Straight run bitumen	
MEP products	All	CIBSE TM65 (specification of MEP constituent materials rather than composite assemblies in Table 2.1 from TM65: 2021)	
Facade build up	All types	Centre for Window and Cladding Technology (CWCT) How to calculate the embodied carbon of facades: a methodology (refer to Appendix B and Appendix C)[16]	

Table 9. Transport distances assumptions.

Transport scenario (both road and sea to be used)	km by road	km by sea
Locally manufactured (ready-mixed concrete)	20	-
Locally manufactured (general), e.g. aggregate, earth, asphalt	50	-
Regionally manufactured, e.g. plasterboard, blockwork, insulation, carpet, glass	80	-
Nationally manufactured, e.g. structural timber, structural steelwork, reinforcement, precast concrete	120	-
European manufactured, e.g. cross-laminated timber (CLT), facade modules	1,500	100
Globally manufactured, e.g. specialist stone cladding	500	10,000

Table 10. Lifespan assumptions.

Building part	Building elements/components	Expected lifespan
Substructure	Piling and foundations	60 years (or building lifespan)
	Lowest ground floor	60 years (or building lifespan)
Superstructure	Structural elements, e.g. columns, walls, beams, upper floor and roof structure	60 years (or building lifespan)
Facade	Opaque modular cladding:	
	Rain screens, timber panels	30 years
	Brick, stone, block and precast concrete panels	60 years
	Glazed cladded/curtain walling	35 years
	Windows and external doors:	
	Hardwood/steel/aluminium windows	30 years
	Doors	20 years
Roof	Roof covering:	
	Single-ply membrane	30 years
	Standing seam metal	30 years
	Tiles, clay and concrete	60 years
Services/MEP	Heat source, e.g. boilers, calorifiers	20 years
	Heat source, e.g. heat pumps (except ground source)	15 years (20 years)
	Space heating and air treatment	20 years
	Central cooling systems (cooling only), e.g. fan coil systems, variable air volume, variable refrigerant volume	15 years
	Ductwork:	
	Galvanised	40 years
	Plastic or flexible	15 years
	Electrical installations	30 years
	Lighting fittings	15 years
	Communications installations and controls	15 years
	Water and disposal installations	25 years
	Rainwater harvesting and grey water collection	30 years
	Sanitaryware	20 years
	Lift and conveyor installations	20 years
Hard landscaping	Asphalt	35 years
	Concrete and stone paving	60 years
	Timber decking	15 years

Table 11. End of life assumptions.

Material	Details	Reuse	Recycling	Incineration with/ without energy from waste	Disposal (landfill and losses)
Concrete	Cast in situ	0%	97.50%	0%	2.50%
	Precast	<1%	96.50%	0%	2.50%
Steel	Hot-rolled structural sections, including plate and tubes	7%	93%	0%	0%
	Light gauge galvanised steelwork, e.g. studwork, cladding framing	5%	93%	0%	2%
	Piles (sheet or bearing)	15%	71%	0%	14%
	Rebar	0%	98%	0%	2%
Masonry	Blockwork	0%	97.50%	0%	2.50%
	Brickwork	<1%	97.50%	0%	2.50%
Timber	Solid timber (untreated, uncoated)	<1%	78%	20%	1%
	Treated, coated timber (non-hazardous)	0%	30%	69%	1%
	Engineered timber (CLT, glulam, etc.)	5%	35%	59%	1%
	Wood-panel products	0%	0%	99%	1%
Aluminium	Sheet	0%	96%	0%	4%
	Profile	<1%	96%	0%	4%
Plasterboard	General	<1%	17%	0%	83%
Glass	All types	0%	61%	0%	39%
Plastics	All types			100%	
Coatings	Paints, intumescent coatings, cementitious sprays	0%	0%	0%	100%
Insulation	Mineral-based		<1%		99%
	Hydrocarbon-based			95%	5%
	Biobased[9]			95%	5%
Asphalt	All types	0%	97.50%	0%	2.50%
Unbound aggregate	All types	0%	97.50%	0%	2.50%
Soils	Includes topsoil and inert non-hazardous earth	0%	97.50%	0%	2.50%

Appendix B – Detailed CO₂e results

The non-decarbonised results are presented in Table 13 and the decarbonised results in Table 14 , on the subsequent pages of this appendix, for the relevant RICS modules summarised in Table 12.

Table 12. Modules as per RICS 2023 guidance.

Module
A0 - Pre-construction stage
[A1-A3] Product stage excl. sequestered carbon
[A1-A3] Sequestered carbon within installed materials/ products
[A4] Transport to and from site
[A5] [A5.1-A5.3] Pre-construction demolition, construction activities and waste management
[A5.4] Transport of construction workers
[B1.1] In-use emissions & removals materials & carbonation
[B1.2] In-use emissions & removals Refrigerant leakage
[B2-B3] Maintenance and repair
[B4] Replacement
[B5] Refurbishment/ planned changes excl. sequestration (where relevant)
[B5] Sequestered carbon related to refurbishment/ planned changes (where relevant)
[B6] [B6.1-B6.3] Energy use
[B7] [B7.1-B7.3] Water use
[B8] User activities
[C1] Deconstruction/demolition process
[C2] Transport to waste processing or disposal facilities
[C3] Waste processing for reuse, recycling and/or energy recovery and disposal
[C4] Waste disposal
[D1] Potential net benefits/loads from reuse, recycling, energy recovery and/ or other recovery
[D2] Potential benefits/loads from exported utilities

Table 13. Detailed results for 138-144 Friar Street by category and module (non-decarbonised and with uncertainty factors included at RIBA Stage 2).

Building element	[A1-A3]	Seq. carbon	[A4]	[A5.1-A5.3]	[A5.4]	[B1.1]	[B1.2]	[B2-B3]	[B4]	[B5]	[B6]	[B7]	[C1]	[C2]	[C3]	[C4]	[D1]	[D2]
Asset level emissions				-	-		81,942	-			3,787,351	143,168	-					-
0.1 Demolition works				111,140	3,402					-								
0.2 Facilitating works	8,684	-8	2,226	12,819	-	-			-	-			-	-	-	8	-	-
1 Substructure	536,414	-23,997	101,712	341,711	878	-10			427	-			-	99,639	8,618	23,499	25	-
2 Superstructure - Structural elements	975,650	-188,964	104,877	79,019	63	-			27,236	-			66,473	152,123	29,026	173,340	109,241	-
2 Superstructure - Building envelope	556,943	-67,809	71,471	41,200	-	-			208,070	-			-	74,022	3,876	73,106	-72,326	-
2 Superstructure - Internal elements	40,624	-89,889	5,546	4,050	-	-			24,957	-			-	5,472	5,485	85,005	57,487	-
3 Finishes	242,652	-52,014	41,012	37,371	-	-			1,361,031	-			-	18,661	4,004	50,909	-8,879	-
4 Fittings, furnishings and equipment (FF&E)	119,327	-108,779	14,566	15,278	55	-		-	274,760	-			-	5,050	-	109,978	-9,927	-
5 Services (MEP)	390,259	-832	55,779	48,698	-	-		78,355	918,286	-			-	15,333	546	70,078	-254,730	-
6 Pre-fabricated buildings and units	-	-	-	-	-	-			-	-			-	-	-	-	-	-
7 Works to existing buildings	-	-	-	-	-	-			-	-			-	-	-	-	-	-
Sub-total	2,870,554	-532,293	397,189	691,287	4,399	-10	81,942	78,355	2,814,768	-	3,787,351	143,168	66,473	370,300	51,554	585,924	-179,109	-
8 External works associated with the project (within boundary)	18,843	-47	11,200	5,155	8	-	-	1,459	41,855	-	-	-	9,374	1,547	-	275	-9,168	-
8 External works associated with the project (outside of boundary)	-	-	-	-	-													
Total (kgCO ₂ e)	2,889,396	-532,340	408,390	696,441	4,407	-10	81,942	79,814	2,856,623	-	3,787,351	143,168	75,847	371,846	51,554	586,198	-188,277	-
Total (kgCO ₂ e/m²)	586	-108	83	141	1	-0	17	16	580	-	769	29	15	75	10	119	-38	-

Table 14. Detailed results for 138-144 Friar Street by category and module (decarbonised and with uncertainty factors included at RIBA Stage 2).

Building element	[A1-A3]	Seq. carbon	[A4]	[A5.1-A5.3]	[A5.4]	[B1.1]	[B1.2]	[B2-B3]	[B4]	[B5]	[B6]	[B7]	[C1]	[C2]	[C3]	[C4]	[D1]	[D2]
Asset level emissions				-	-		40,971	-			979,434	26,247	-					-
0.1 Demolition works				111,140	3,402			-		-								
0.2 Facilitating works	8,684	-8	2,226	12,819	-	-		-	-	-			-	-	-	8	-	-
1 Substructure	536,414	-23,997	101,712	341,711	878	-10		-	214	-			-	49,820	8,618	23,499	12	-
2 Superstructure - Structural elements	975,650	-188,964	104,877	79,019	63	-		-	13,618	-			33,237	76,061	29,026	173,340	54,621	-
2 Superstructure - Building envelope	556,943	-67,809	71,471	41,200	-	-		-	104,035	-			-	37,011	3,876	73,106	-36,163	-
2 Superstructure - Internal elements	40,624	-89,889	5,546	4,050	-	-		-	12,478	-			-	2,736	5,485	85,005	28,743	-
3 Finishes	242,652	-52,014	41,012	37,371	-	-		-	680,516	-			-	9,330	4,004	50,909	-4,440	-
4 Fittings, furnishings and equipment (FF&E)	119,327	-108,779	14,566	15,278	55	-		-	137,380	-			-	2,525	-	109,978	-4,963	-
5 Services (MEP)	390,259	-832	55,779	48,698	-	-		39,178	459,143	-			-	7,666	546	70,078	-127,365	-
6 Pre-fabricated buildings and units	-	-	-	-	-	-		-	-	-			-	-	-	-	-	-
7 Works to existing buildings	-	-	-	-	-	-		-	-	-			-	-	-	-	-	-
Sub-total	2,870,554	-532,293	397,189	691,287	4,399	-10	40,971	39,178	1,407,384	-	979,434	26,247	33,237	185,150	51,554	585,924	-89,555	-
8 External works associated with the project (within boundary)	18,843	-47	11,200	5,155	8	-	-	729	20,928	-	-	-	4,687	773	-	275	-4,584	-
8 External works associated with the project (outside of boundary)	-	-	-	-	-													
Total (kgCO ₂ e)	2,889,396	-532,340	408,390	696,441	4,407	-10	40,971	39,907	1,428,312	-	979,434	26,247	37,923	185,923	51,554	586,198	-94,139	-
Total (kgCO ₂ e/m ²)	586	-108	83	141	1	-0	8	8	290	-	199	5	8	38	10	119	-19	-

Appendix C – Other environmental indicators

Environmental impacts were evaluated across different indicators, the definitions of which are presented below.

Ozone Depletion Potential (ODP)

Ozone Depletion Potential quantifies the potential of substances released to the atmosphere to damage the stratospheric ozone layer. Results are expressed relative to the impact of CFC-11 and reported as kilograms of CFC-11 equivalent (kg CFC-11 eq).

Abiotic Depletion Potential – Elements (ADPE)

Abiotic Depletion Potential for Elements measures the consumption of non-renewable mineral and metal resources. It reflects the potential scarcity of these resources resulting from extraction and use, expressed as kilograms of antimony equivalent (kg Sb eq).

Abiotic Depletion Potential – Fossil Fuels (ADPF)

Abiotic Depletion Potential for Fossil Fuels measures the depletion of non-renewable energy resources such as coal, oil and natural gas. The indicator is expressed in megajoules (MJ) and represents the total fossil energy consumed throughout the life cycle.

Global Warming Potential Fossil (GWP-F)

GWP Fossil quantifies greenhouse gas emissions arising specifically from fossil carbon sources, such as the combustion of coal, oil and natural gas. It excludes biogenic carbon and land-use related impacts and is expressed in kgCO₂e.

Global Warming Potential Biogenic (GWP-B)

GWP Biogenic measures climate change impacts associated with biogenic carbon flows, including the uptake, storage and release of carbon by biomass and bio-based materials. Results are expressed as kgCO₂e and may be positive or negative depending on carbon storage effects.

Global Warming Potential Land Use and Land Use Change (GWP-LULUC)

GWP-LULUC assesses greenhouse gas emissions associated with land use and land use change, such as forestry activities, agricultural land conversion or changes in vegetation cover. The results are expressed as kgCO₂e.

Acidification Potential (EN)

Acidification measures emissions that contribute to the formation of acidic compounds in the environment, which can damage soils, water bodies, vegetation and ecosystems. The indicator is expressed as moles of hydrogen ion equivalent (mol H⁺ eq).

Eutrophication, Marine (EN)

Marine eutrophication measures the potential for nutrient emissions, particularly nitrogen compounds, to cause excessive growth of algae and aquatic plants in marine environments. This can reduce oxygen levels and negatively affect marine ecosystems. Results are expressed as kilograms of nitrogen equivalent (kg N eq).

Eutrophication, Freshwater (EN)

Freshwater eutrophication assesses the potential for nutrient releases, primarily phosphorus compounds, to cause excessive biological growth in lakes, rivers and other freshwater bodies. The indicator is expressed as kilograms of phosphorus equivalent (kg P eq).

Eutrophication, Terrestrial (EN)

Terrestrial eutrophication measures the impact of nutrient deposition, particularly nitrogen compounds, on terrestrial ecosystems. Excessive nutrient enrichment can alter plant communities and reduce biodiversity. Results are expressed as moles of nitrogen equivalent (mol N eq).

Photochemical Ozone Formation (EN)

Photochemical ozone formation measures emissions that contribute to the creation of ground-level ozone (smog) through reactions in the atmosphere. Elevated ozone concentrations can harm human health, vegetation and ecosystems. Results are expressed as kilograms of non-methane volatile organic compound equivalent (kg NMVOC eq).

Water Use (EN)

Water Use quantifies the potential environmental impacts associated with freshwater consumption and deprivation across the life cycle. It reflects the extent to which water resources are withdrawn and unavailable for other users or ecosystems and is expressed in cubic metres of water deprivation equivalent (m³ depriv.).

Mass of Materials, Total

Mass of Materials represents the total quantity of materials used throughout the assessed life cycle, reported in tonnes (t). This indicator provides an overview of material resource consumption and can be used to assess material efficiency and circular economy performance.

Results

The results are shown in Figure 10 to the right and in Table 15 on the following page.

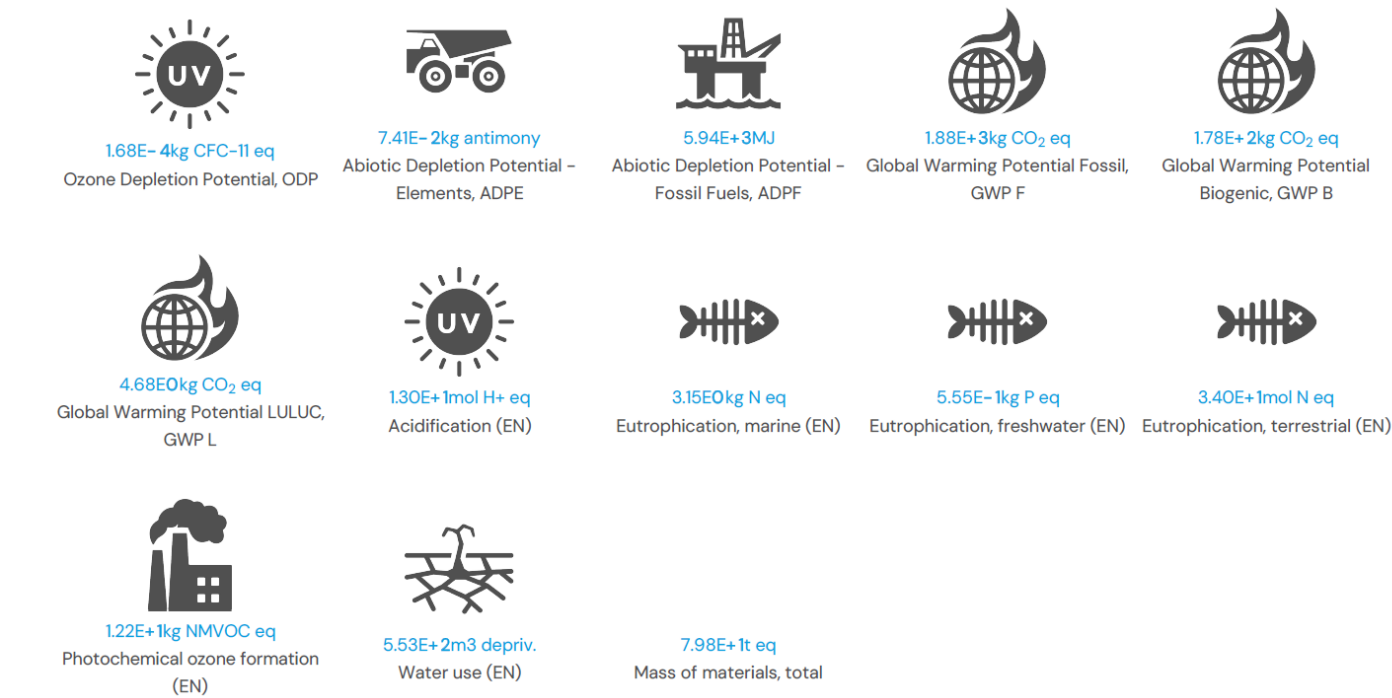


Figure 10. Summary of environmental impacts across different indicators.

Table 15. Proposed scheme performance for a range of environmental indicators across all life-cycle reporting modules.

Indicator	Unit	A (construction)	B (Use)	C (end of life)	D (benefits beyond boundary)	A-D (Life cycle)
Ozone Depletion Potential, ODP	kg CFC-11 e	3.14E-05	1.36E-04	1.46E-06	-9.61E-07	1.68E-04
Abiotic Depletion Potential – Fossil Fuels, ADPF	MJ	3.95E-02	4.95E-02	4.26E-04	-1.54E-02	7.41E-02
Global Warming Potential Fossil, GWP F	kg CO ₂ e	2.16E+03	4.16E+03	1.53E+02	-5.30E+02	5.94E+03
Global Warming Potential Biogenic, GWP B	kg CO ₂ e	7.10E+02	1.15E+03	1.10E+02	-9.19E+01	1.88E+03
Global Warming Potential LULUC, GWP L	kg CO ₂ e	-1.13E+02	1.53E+02	7.66E+01	6.16E+01	1.78E+02
Acidification (EN)	mol H+ eq	1.65E+00	3.09E+00	3.41E-02	-8.74E-02	4.68E+00
Eutrophication, marine (EN)	kg N eq	6.32E+00	7.49E+00	7.25E-01	-1.53E+00	1.30E+01
Eutrophication, freshwater (EN)	kg P eq	1.37E+00	1.60E+00	3.23E-01	-1.37E-01	3.15E+00
Eutrophication, terrestrial (EN)	mol N eq	3.42E-01	3.20E-01	9.58E-03	-1.17E-01	5.55E-01
Photochemical ozone formation (EN)	kg NMVOC eq	1.54E+01	1.67E+01	3.53E+00	-1.67E+00	3.40E+01
Water use (EN)	m ³ depriv.	4.72E+00	6.75E+00	1.27E+00	-5.21E-01	1.22E+01
Mass of materials, total	t eq	1.70E+02	4.59E+02	1.35E+01	-8.95E+01	5.53E+02

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