Whole Life Cycle Assessment

20-24 Pope's Road, Brixton, London, SW9

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APPENDICES

1.0 EXECUTIVE SUMMARY

A Whole Life Cycle Assessment (WLCA) in accordance with the GLA requirements has been undertaken for the proposed development at 20-24 Pope's Road, Brixton. The WLCA has been run for the entire building envelope, in line with the GLA requirements. This has been based on materials data provided by the project design team for applicable building elements required by the GLA methodology.

This WLCA seeks compliance with policies as set out in section 5.0 and has been undertaken using Bionova Ltd's One Click LCA and in accordance with BS EN 15978 and the RICS Professional Statement: Whole Life Carbon assessment for the built environment RICS. This WLCA has assessed the entirety of following modules for the Pope's Road development;

Module A1 – A5 (Product sourcing and construction stage);
Module B1 – B7 (Use stage);
Module C1 – C4 (End of life stage); and
Module D (Benefits and loads beyond the system boundary).

Material types and quantities were requested from the design team. Workshops took place with the following disciplines to review the material inputs and discuss viable embodied carbon reduction strategies;

- HDR – MEP
- Adjaye Associates – Architects
- HDR | – Sustainability
- AKT UK – Structures

Current WLC assessment Benchmarks for Office buildings are given in the results table below and *Table 8* (See section 9.0), as listed in the 'Draft Whole Life-Cycle Carbon Assessments Guidance' October 2020 and are compared to results at this stage for the Pope's Road development.

Appendix A includes a completed GLA WLC assessment template for the Pope's Road development.

An options appraisal was undertaken, and the following recommendations were included;

- The pile length has been reduced to 30m with a considerable reduction in the volume of concrete for both 900mm piles and 600mm piles
- Reinforcement steel has been reduced by 25%
- An aluminium curtain wall system has been utilised over a steel curtain wall system

The table below summarises the results with the current electricity grid;

	GLA Benchmark ($KgCO_2e/m^2$)	Aspirational GLA Benchmark ($KgCO_2e/m^2$)	20-24 Pope's Road Carbon ($KgCO_2e/m^2$)	20-24 Pope's Road Carbon Hero's Rating ($KgCO_2e/m^2$)
Carbon to Complete (A1-A5)	900 – 1000	550-600	520	
Carbon Over Life (B-C excluding B6 & B7)	400 - 500	250-300	168	
WLCA - Current Electricity (A-D)			1696	
WLCA Future Electricity (A-D)			890	
Total Embodied Carbon (A1-A4, B4-B5, C1-C4)			658	E
Super Structure (A1-A4, B4-B5, C1-C4)			336	B
Sub Structure (A1-A4, B4-B5, C1-C4)			305	B

The analysis suggests that the 20-24 Pope's Road development has been designed in a carbon efficient manner and meets GLA Carbon benchmarks. Further opportunities for carbon reduction will be explored at a later stage.

2.0 INTRODUCTION

HDR have been appointed by 'Hondo Enterprises' to carry out a Whole Life Cycle Assessment (WLCA) for the proposed 20-24 Pope's Road development located in the London Borough of Lambeth. This Statement is based on information provided by the project team in relation to the building design as it stands at RIBA Stage 2.

The WLCA was completed at RIBA Stage 2 to inform the Applicant, the design team and the GLA on the benchmark whole lifecycle carbon (WLC) performance for the proposed development. The WLCA was completed using Bionova Ltd's One Click LCA tool employing the extensive material databases contained in the software tool.

3.0 SITE AND PROPOSED DEVELOPMENT

3.1 Site Description

The proposed Pope's Road site is located and bound by two railway viaducts. It is positioned between both Brixton Station Road and Atlantic Road, the two main artery roads that run from the East to West towards Brixton Road and is currently vacant. The site area is 0.26 hectares.

3.2 Proposed Development

The proposals include;

- 27,390 m^2 (GIA)

Demolition of the existing building and erection of a part five, part nine and part twenty storey building comprising flexible Class A1 (shops)/A3 (restaurants and cafes)/B1 (business)/D1 (non-residential Institutions)/D2 (assembly and leisure) uses at basement, ground and first floor levels, with restaurant (Class A3) use at eighth floor level and business accommodation (Class B1) at second to nineteenth floor levels, with plant enclosures at roof level, and associated cycle parking, servicing and enabling works.

4.0 APPROACH

This WLCA has been undertaken using Bionova Ltd's One Click LCA and in accordance with BS EN 15978 and the RICS Professional Statement: Whole Life Carbon assessment for the built environment RICS. This WLCA has assessed the entirety of following modules for the Pope's Road development;

Module A1 – A5 (Product sourcing and construction stage);
Module B1 – B7 (Use stage);
Module C1 – C4 (End of life stage); and
Module D (Benefits and loads beyond the system boundary).

Material types and quantities were requested from the design team. A workshop took place with the following disciplines to review the material inputs and discuss viable embodied carbon reduction strategies;

- HDR – MEP
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- HDR | – Sustainability
- AKT UK – Structures

5.0 POLICIES

5.1 National Planning Policy Framework and Planning Policy Statements (February 2019)

The National Planning Policy Framework (2019) sets out the challenges presented by climate change. Paragraph 148 states:

"The planning system should support the transition to a low carbon future in a changing climate…It should help to: shape places in ways that contribute to radical reductions in greenhouse gas emissions, minimise vulnerability and improve resilience; encourage the reuse of existing resources, including the conversion of existing buildings; and support renewable and low carbon energy and associated infrastructure."

Paragraph 150 states:

"New development should be planned for in ways that: a) avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure;"

5.2 The Publication London Plan 2020

The Mayor of London has formally approved a new London Plan, the 'Publication London Plan'. It has been sent to the Secretary of State approval prior to being fully adopted. The plan includes the following relevant policies.

- Policy GG2 Making the best use of land
- Policy GG3 Creating a healthy city
- Policy GG6 Increasing efficiency and resilience
- Policy D1A Infrastructure requirements for sustainable densities

- Policy D1B Optimising site capacity through the design-led approach
- Policy D13 Noise
- Policy G5 Urban Greening
- Policy G6 Biodiversity and access to nature
- Policy G7 Trees and woodlands
- Policy G8 Food growing
- Policy SI1 Improving air quality
- Policy SI2 Minimising greenhouse gas emissions
- Policy SI3 Energy infrastructure
- Policy SI4 Managing heat risk
- Policy SI5 Water infrastructure
- Policy SI7 Reducing waste and supporting the circular economy
- Policy SI12 Flood risk management
- Policy SI13 Sustainable drainage
- Policy T1 Strategic approach to transport
- Policy T5 Cycling
- Policy T6 Car parking

In particular, Policy SI 2 Minimising greenhouse gas emissions – Major development should be net zero-carbon. This means reducing greenhouse gas emissions in operation and minimising both annual
and peak energy demand in accordance with the energy hierarchy.

5.3 GLA Whole Life Cycle Carbon Assessments Guidance Consultation Draft October 2020

Guidance document includes the following policy background.

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

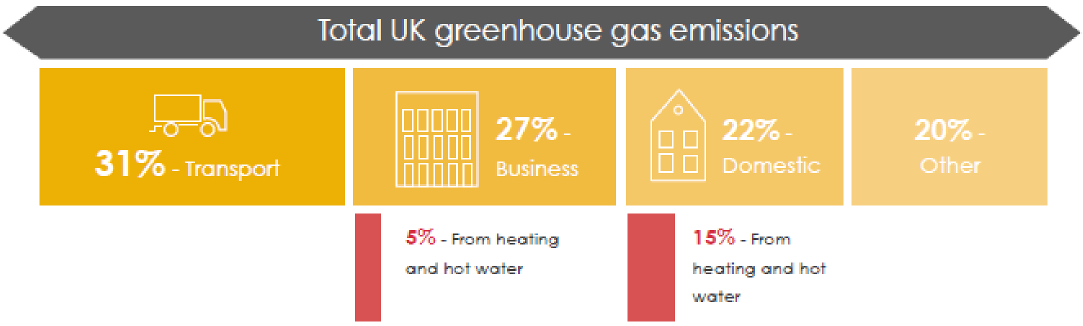
The Mayor's net zero-carbon target continues to apply to the operational emissions of a building. The WLC requirement is not subject to this target but, as set out in London Plan Policy SI 2, planning applicants are required to calculate the embodied emissions of the development, as well as the operational emissions, and demonstrate how these can be reduced as part of the WLC assessment. Planning applicants should continue to follow the GLA's Energy Assessment Guidance to assess and reduce operational emissions and insert the relevant information into the WLC assessment.

This document explains how to calculate WLC emissions and the information that needs to be submitted to comply with the policy. It also includes information on design principles and WLC benchmarks to aid planning applicants in designing buildings that have low operational carbon and low embodied carbon.

6.0 WHOLE LIFE CYCLE ASSESSMENT METHODOLOGY

6.1 WLCA Overview

In the UK, 49% of annual carbon emissions are attributable to buildings.



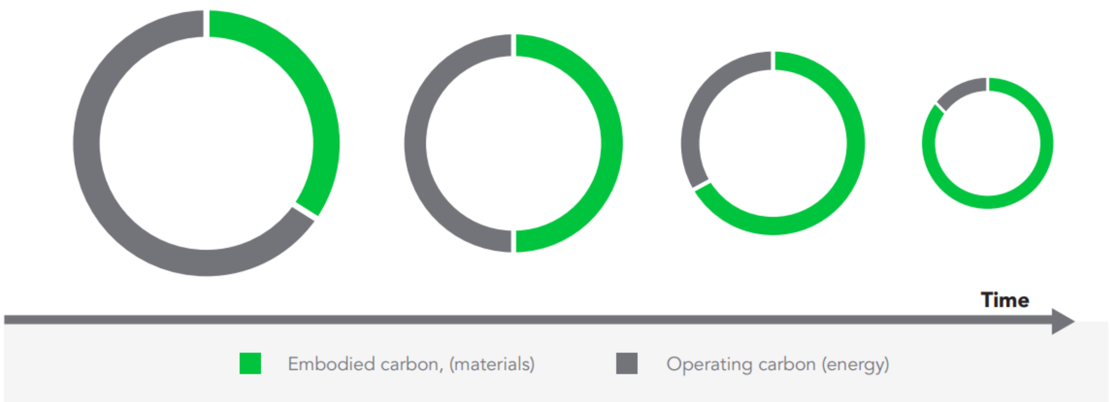
Source: Information in figure 0-01 has been developed from a variety of sources. 1. National Statistics, Annex: 1990-2017 UK Greenhouse Gas Emissions, Final Figures by End User, Issued 28/03/19. 2. Committee on Climate Change, UK housing: Fit for the future? February 2019. 3. Committee on Climate Change, Reducing UK Emissions - 2019 Progress Report to Parliament. 4. Environmental Change Institute, 40% House, 2005

Whole life carbon of a building is formed of two key components:

Operational Carbon: emissions of carbon dioxide during the operational or in-use phase of a building. A new building with net zero operational carbon does not burn fossil fuels, is 100% powered by renewable energy, and achieves a level of energy performance in-use in line with our national climate change targets.

Embodied Carbon: carbon dioxide emitted during the manufacture, transport and construction of building materials, together with end of life emissions. Best Practice targets for embodied carbon are met, and the building is made from re-used materials and can be disassembled at its end of life in accordance with circular economy principles.

The use of construction products leads to a wide range of environmental and social impacts across the life cycle of a building project, through initial procurement, wastage, maintenance and replacement. Construction products make a highly significant contribution to the overall life cycle impacts of a building. In some cases, they may even outweigh operational impacts. The introduction of Part L into the building regulations for England and Wales has led to reductions in the operational energy consumption of buildings and these regulations are being progressively tightened. As a result, greenhouse gas emissions from other aspects of buildings, such as embodied emissions, are becoming increasingly important in terms of reducing the overall emissions that lead to climate change over the building's lifetime. The graph below highlights the anticipated changing balance between the impact of embodied carbon and operating carbon over time.



Source: The Embodied Carbon Review, Bionova Ltd, 2018

To stay within the IPCC's1 1.5 degrees scenario, significant embodied carbon reductions are necessary. The World Green Building Council believes that to meet our climate change targets all new buildings must operate at net zero carbon by 2030 and all buildings operate at net zero carbon by 2050.

Life cycle assessment (LCA) is one of the best methodologies to allow building professionals to understand the energy use and other environmental impact associated with all the phases of a building's life cycle. This is often known as embodied carbon or energy assessment. The embodied energy of a building is the energy required to make, deliver, assemble and dispose of all the materials used in its construction, refurbishment and demolition. Embodied carbon is the CO_2 emissions released due to the embodied energy plus any process emissions, such as the CO_2 released by the chemical reaction when cement is produced.

The embodied carbon of a building is calculated by measuring the quantity of every material used over the life of the building and multiplying this by an emissions factor for each. To this is added emissions due to delivery of materials to site, construction activities, and waste.

Source: Bionova Ltd

The LCA process is governed under ISO 14000, a series of international standards addressing environmental management. The framework for appraising the environmental impacts of the built environment specifically is provided by EN 15978: 2011. It is part of the EN 15643 family of standards for the sustainability assessment of buildings. It sets out the principles for whole life assessment of the environmental impacts from built projects based on LCA.

For whole life principles to be integrated into the design, procurement and construction processes and beyond, and for project teams to be engaged in a timely fashion, carbon assessments should be carried out at key project stages from concept design to practical completion.

6.2 WCLA Scope

Whole Life-Cycle Carbon (WLC) emissions are the carbon emissions resulting from the construction and the use of a building over its entire life, including its demolition and disposal. They capture a building's operational carbon emissions from both regulated and unregulated energy use, as well as its embodied carbon emissions, i.e., those associated with raw material extraction, manufacture and transport of building materials, construction and the emissions associated with maintenance, repair and replacement as well as dismantling, demolition and eventual material disposal. A WLC assessment provides a true picture of a building's carbon impact on the environment

[1] Intergovernmental Panel on Climate Change https://www.ipcc.ch/

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	x					x	x	x				x		

Table 1 - Life Cycle Stages According to EN15804:2012 included in WLCA

Description of the life cycle stages, and analysis scope are provided in the table below:

A1-A3 Construction Materials	Raw material supply (A1) includes emissions generated when raw materials are taken from nature, transported to industrial units for processing and processed. Loss of raw material and energy are also considered. Transport impacts (A2) include exhaust emissions resulting from the transport of all raw materials from suppliers to the manufacturer's production plant as well as impacts of production of fuels. Production impacts (A3) cover the manufacturing of the production materials and fuels used by machines, as well as handling of waste formed in the production processes at the manufacturer's production plants until end-of-waste state.
A4 Transportation to site	A4 includes exhaust emissions resulting from the transport of building products from manufacturer's production plant to building site as well as the environmental impacts of production of the used fuel.
A5 Construction/installation process	A5 covers the exhaust emissions resulting from using energy during the site operations, the environmental impacts of production processes of fuel and energy and water as well as handling of waste until the end-of-waste state.
B1-B5 Maintenance and material replacement	The environmental impacts of maintenance and material replacements (B1-B5) include environmental impacts from replacing building products after they reach the end of their service life. The emissions cover impacts from raw material supply, transportation and production of the replacing new material as well as the impacts from manufacturing the replacing material as well as handling of waste until the end-of-waste state.
B6 Energy use	The considered use phase energy consumption (B6) impacts include exhaust emissions from any building level energy production plus the environmental impacts of production processes of fuel and externally produced energy. Energy transmission also considered.
B7 Water use	The considered use phase water consumption (B7) impacts include the environmental impacts of production processes of fresh water and the impacts from wastewater treatment.

C1-C4 Deconstruction	The impacts of deconstruction include impacts for processing recyclable construction waste flows for recycling (C3) until the end-of-waste stage or the impacts of pre-processing and landfilling for waste streams that cannot be recycled (C4) based on type of material. Additionally, deconstruction impacts include emissions caused by waste energy recovery.
D External impacts/end-of-life benefits	The external benefits include emission benefits from recycling recyclable building waste. Benefits for re-used or recycled material types include positive impact of replacing virgin-based material with recycled material and benefits for materials that can be recovered for energy cover positive impact for replacing other energy streams based on average impacts of energy production.

Table 2 - Description of life cycle stages included in EN15804:2012 and analysis scope included in WLCA

Assessed impact categories are described below:

Impact category	Unit	Description
Global warming potential (greenhouse gases)	$kgCO_2$ eq	Describes changes in local, regional, or global surface temperatures caused by an increased concentration of greenhouse gases in the atmosphere. Greenhouse gas emissions from fossil fuel burning has been strongly correlated with two other impact categories: acidification and smog. Often called "carbon footprint".
Acidification potential	$kgSO_2$ eq	Describes the acidifying effect of substances in the environment. Substances such as carbon dioxide dissolve readily in water, increasing the acidity, which contributes to global phenomena such as ocean acidification (IPCC 2014).
Eutrophication potential	kgPO4-eq	Describes the effect of adding mineral nutrients to soil or water, which causes certain species to dominate an ecosystem, compromising the survival of other species and sometimes resulting in die-off of populations.
Ozone depletion potential	kgCFC11eq	Describes the effect of substances in the atmosphere to degrade the ozone layer, which absorbs and prevents harmful solar UV rays from reaching Earth's surface.
Formation of ozone of lower atmosphere	kgC2H4eq	Describes the effect of substances in the atmosphere to create photochemical smog. Also known as summer smog.
Non-Hazardous Waste Disposal	kg	Describes the effect of waste containing substances, or which has properties, that might make it harmful to human health or the environment.

Table 3 - Description of WLCA Assessment categories

The table below lists the building elements included and excluded in the WLCA model:

Building Part/Element Group	Building element	Included / excluded
Demolition	0.1 Toxic/Hazardous/Contaminated Material treatment	N/A
	0.2 Major Demolition Works	N/A
0 - Facilitating works	0.3 & 0.5 Temporary enabling works	N/A
	0.4 Specialist groundworks	N/A

1- Substructure	1.1 Substructure	Y
	2.1 Frame	Y
	2.2 Upper floors incl. balconies	Y
	2.3 Roof	Y
	2.4 Stairs and ramps	Y
	2.5 External walls	Y
	2.6 Windows and external doors	Y
	2.7 Internal walls and partitions	Y
	2.8 Internal doors	N
3 - Finishes	3.1 Wall finishes	N
	3.2 Floor finishes	N
	3.3 Ceiling finishes	N
4- Fittings, furnishings and equipment (FF&E)	4.1 FF&E	N
5 - Building services/MEP	5.1 – 5.4 Building services	Y
6 - Prefabricated Buildings and Building Units	6.1 Prefabricated buildings and building units	N/A
7 Work to Existing Building	7.1 Minor demolition and alteration works	N/A
8 - External works	8.1 Site preparation works	N
	8.2 Roads, paths, pavings and surfacings	Y
	8.3 Soft landscaping, planting and irrigation systems	N
	8.4 Fencing, railings and walls	N
	8.5 External fixtures	N
	8.6 External drainage	N
	8.7 External services	N
	8.8 Minor building works and ancillary buildings	N/A

Table 4 - Building elements included and excluded in the WLCA

6.3 Environmental Data Sources and One Click

One Click LCA was used in the undertaking of this LCA. The tool supports the CML2 impact assessment database and methodology (2002-2012 or newer) methodology and all assessed impact categories. All the datasets in the tool follow EN 15804 standard. The software is fully compliant with the EN 15978 standard. One Click LCA has been third party verified by the Instytut Techniki Bodowlanej (ITB) for compliancy with the following LCA standards: EN 15978, ISO 21931–1 and ISO 21929, and data requirements of ISO 14040 and EN 15804.

6.4 Operational Carbon (Energy)

The energy statement accompanying the planning application details how operational energy use has been minimised.

The operational energy figure used for this WLCA has been calculated in accordance with TM54 and can be taken as an indication of the likely real-world situation. The CIBSE TM54 analysis was undertaken based on a tailored planning stage Part L2A model and industrial benchmarks to estimate regulated and unregulated energy. The model under the TM54 methodology utilises available design information including in-operation profile of the building. The model results include calculations for the annual energy associated with not only the regulated elements but also the unregulated elements such as IT equipment, lift, refrigeration systems, external lighting, CCTV etc.

[2] CML, is the University of Leiden's Institute of Environmental Sciences

Decarbonised operational energy has been included in the GLA WLC assessment results table in appendix A of this report using Oneclick Electricity, Non-2050 compliant - Steady Progression 2050 (FES 2020).

Operational water use has also been included in the GLA WLC assessment results table in appendix A of this report and has been calculated using the BREEAM assessment method for water consumption also considering wastewater treatment. The Carbon factor used to calculate kg/CO_2e (0.0001402 KgCO_2e/L) is that given in the Thames Water 'Annual Report & Sustainability Report 2020/2021'.

7.0 RESULTS

7.1 Whole Life Carbon – Current Electricity (SAP10)

The total Whole Life Carbon covering;

- Product Stage (A1-A3)
- Construction Process Stage (A4-A5)
- Usage Stage (B4-B7)
- End-of-Life Stage (C1-C4)

for the project is **1089 kg/CO_2e/m^2** as calculated using 'One Click' software (see Appendix A – Assessment 1).

Figure 1 shows that approximately 77% of the carbon over the life cycle of the development is associated with operation energy usage and 17% is due to carbon associated with material use. Figure 2 shows that the biggest material carbon contribution to the overall WLC is precast due to 8.1% carbon emissions.

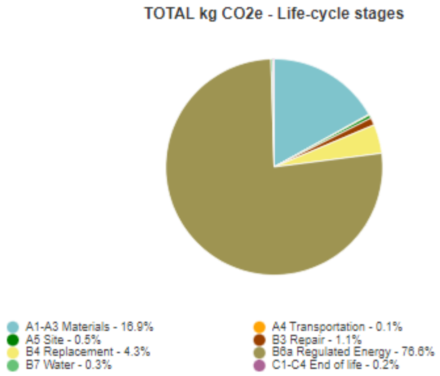


Figure 1 - Breakdown of WLC KgCO2e by lifecycle stages

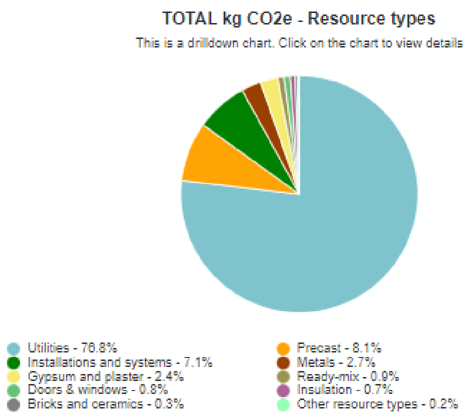
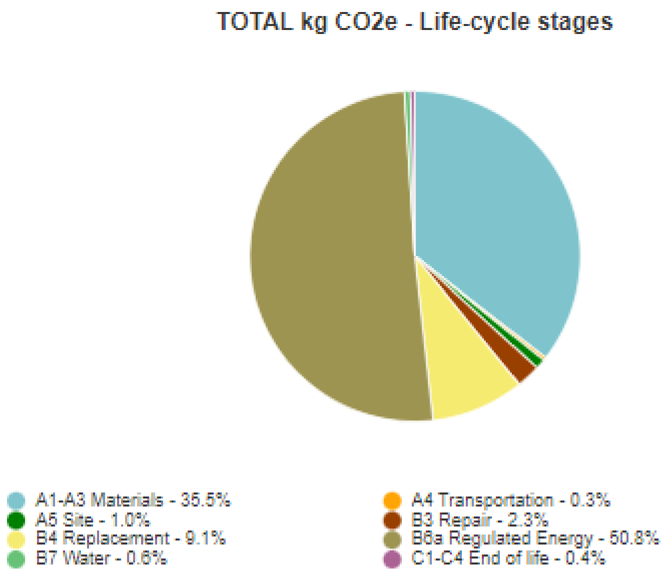


Figure 2 - Breakdown of WLC by resources type

7.2 Whole Life Carbon – Average Future Electricity – Steady Progression 2050 scenario (FES 2020)

The total WLC using the Steady Progression 2050 Scenario (FES 2020) is **954 CO_2e/m^2** (see Appendix A – Assessment 2).

Figure 3 shows that under Steady Progression 2050 Scenario approximately 51% of the carbon over the life cycle of the development is associated with operation energy usage and 35.5% is due to carbon associated with material use. Figure 4 shows that utilities under Steady Progression 2050 Scenario has reduced to approximately 51% in line with the reduction in carbon from grid electricity.



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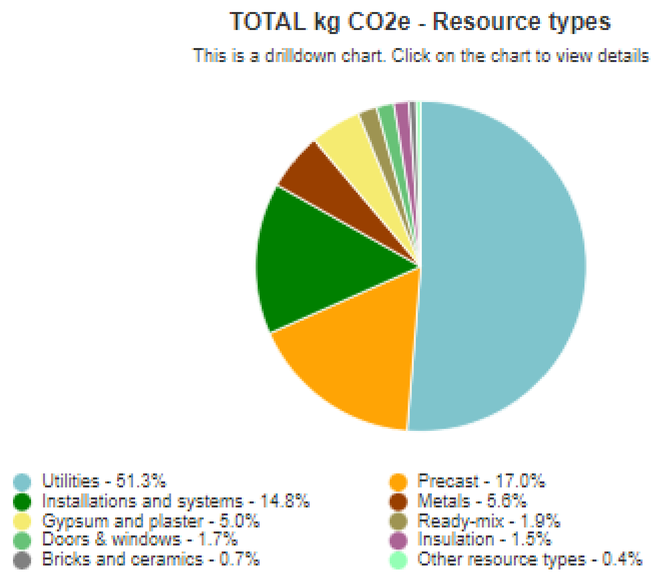

Figure 2 - Breakdown of WLC by resources type

7.3 Total Embodied Carbon – SAP 10

The total embodied material carbon covering;

- Product Stage (A1-A3)
- Construction Process Stage (A4-A5)
- Usage Stage excluding operational energy (B4-B5)
- End-of-Life Stage (C1-C4)

for the project is **658 kg/CO_2e/m^2** as calculated using 'One Click' software and shown in figure 5. One Click embodied carbon benchmarks for the proposed design shows in figure 5 that over 30% of the total material carbon is associated with the vertical structures.

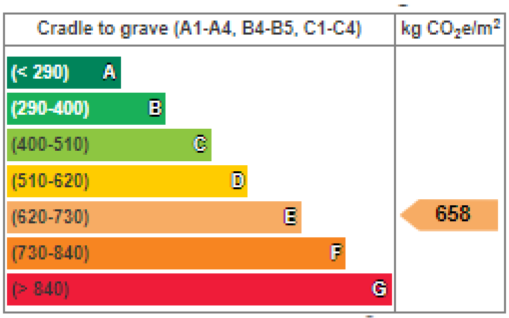

Figure 3 - Total Material Carbon One Click Carbon Heroes benchmarking

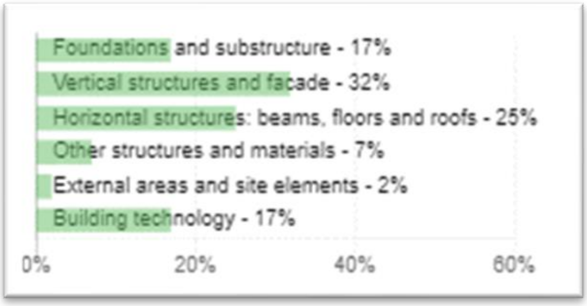

Figure 4 - Breakdown by function of carbon associated with Total Material Carbon

Total Carbon at Construction Completion

The total embodied construction carbon covering;

- Product Stage (A1-A3)
- Construction Process Stage (A4-A5)

for the project is **520 kg/CO_2e/m²** as calculated using 'One Click' software (see Appendix A – Assessment 1).

The total Carbon at Completion of 520 kg CO_2e/m² is less than the GLA Carbon at Completion office benchmark of **1000 kg CO_2e/m²** and less than the GLA aspirational target of **600 kg CO_2e/m².**

7.3.1 Proposed Design Benchmark – Superstructure

The total Material Carbon of the proposed superstructure design for Pope's Road has been calculated as **336 kg CO_2e/m²**. Figure 7 below shows One Click embodied carbon benchmarks for the proposed superstructure as B. As shown in figure 8 the carbon from the vertical facades is 50% and the carbon for the horizontal structure is 39%.

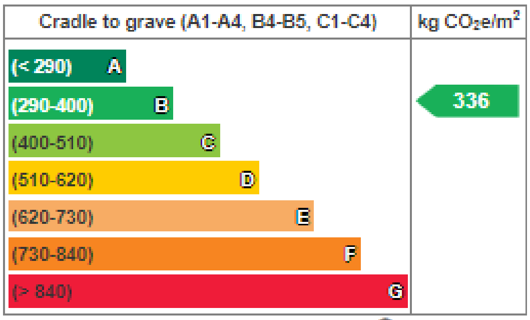

Figure 5 - Superstructure One Click Embodied Carbon benchmarking

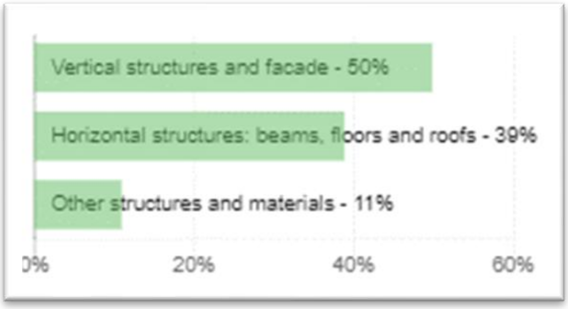

Figure 6 - Breakdown by function of carbon associated with the Superstructure

Figure 9 shows 'Product Stage' emissions, associated with raw material supply, transport to manufacturing plant and manufacturing processes, form the largest contribution to the global warming potential of the superstructure. Figure 10 shows the material contributing the most to kgCO_2e emissions was found to be precast (50.8%), followed by gypsum and plaster (18.6%), then metal (9.8%).

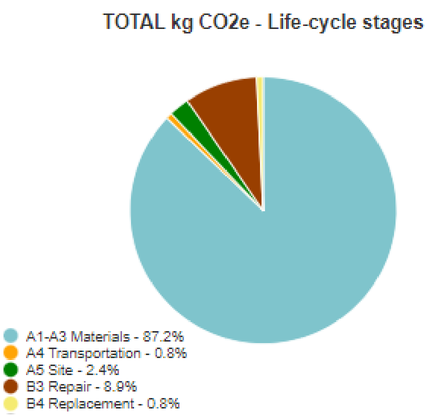

Figure 9 - Breakdown of Superstructure KgCO_2e by lifecycle stages

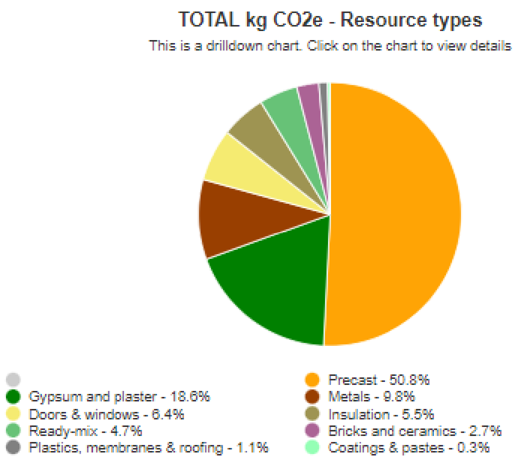

Figure 10 - Breakdown of Superstructure by resources type

Options Appraisal Superstructure

As part of the workshop with the design team the superstructure has been refined as detailed below.

Superstructure			
Option	**kg CO_2e/m^2 GIFA (60 year)**	**Change**	**Description of Change**
Option 1	336	N/A chosen option	**N/A chosen option:** 60 % recycled content in steel reinforcement.
Option 2	817	+143%	Concrete frame; Over specified to reduce the risk. Reinforced steel 0% Recycled content.

Table 5 - Summary of assessed superstructure options

7.3.2 Proposed Design Benchmark – Substructure and Hard Landscaping

The total Material Carbon of the proposed substructure design for Pope's Road has been calculated as 305 kg CO_2e/m^2. Figure 11 below shows One Click carbon heroes benchmarks for the proposed superstructure as B. The carbon associated with substructure and hard landscaping is extremely low as the proposed design minimises the requirement for new foundations. Figure 12 shows that 98% of the carbon associated with the new substructure and hard landscaping is associated with the new foundations and the remaining with the external landscaping and other structures.

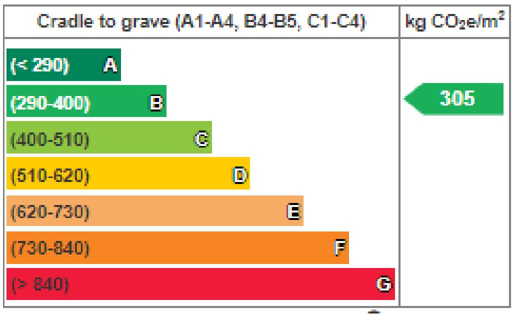

Figure 7 - Substructure One Click Carbon Heroes benchmarking

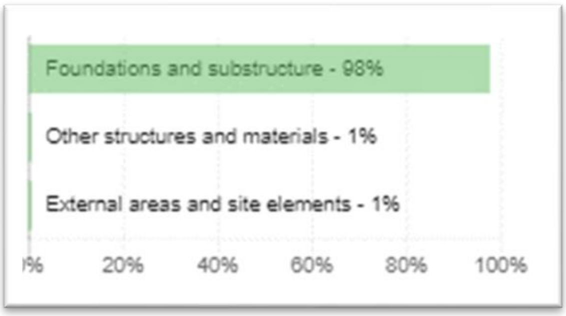

Figure 8 - Breakdown by function of carbon associated with the Substructure

Figure 13 shows the 'Product Stage' emissions, associated with raw material supply, transport to manufacturing plant and manufacturing processes, form the largest contribution to the global warming potential of the substructure and hard landscaping. The material contributing the most to $kgCO_2e$ emissions shown in Figure 14 was found to be precast (85.2%), followed by Metals (13.6%).

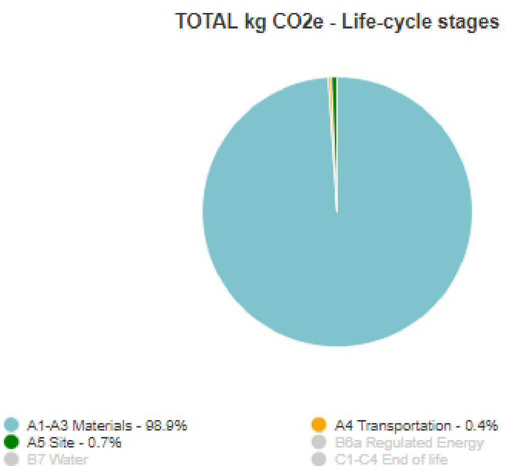

Figure 9 - Breakdown of Substructure $KgCO_2e$ by lifecycle stages

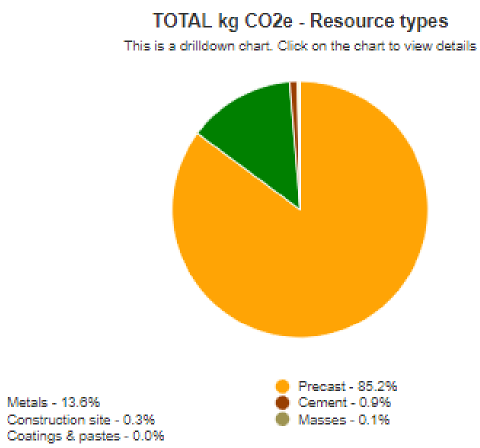

Figure 10 - Breakdown of substructure by resources type

Options appraisal Substructure and Hard Landscaping

As part of the workshop with the design team two Substructure options additional to the chosen option detailed above were assessed and summarised in table 6.

Substructure & Hard Landscaping			
Option	**kg CO_2e/m^2 GIFA (60 year)**	**Change**	**Description of Change**
Option 1	305	N/A chosen option	**N/A chosen option:** Piled foundations; RC Pile caps; Concrete ground floor slab Recycled content within reinforcement
Option 2	698	+129%	Over engineered to reduce risk

Table 6 - Summary of assessed substructure options

7.4 B6 Operation Energy

The proposed development is an all-electric system. The B6 operational energy using current grid electricity carbon factors (SAP 10) is 2,300 $kgCO_2e/m^2$(GIA) and 730 $kgCO_2e/m^2$(GIA) for future decarbonised grid electricity.

7.5 B7 Operation Water Usage

Operational water use has been calculated using carbon factors based on those given in the Thames Water 'Annual Report & Sustainability Report 2020/2021' and found to be 31$kgCO_2e/m^2$(GIA).

8.0 OPPORTUNITIES IDENTIFIED TO REDUCE EMBODIED CARBON

Making efficient use of resources is the best method of reducing embodied carbon:

- Considering material type, its efficient use, and expected lifespan
- Choose low carbon versions of materials
- Minimise wastage on site, consider construction processes and design for adaptability, disassembly and reuse

The London Energy Transformation Initiative's (LETI) 'Supplementary Guidance to the Climate Emergency Design Guide – LETI Embodied Carbon Primer' highlights the below 'rules of thumb' strategies for reducing embodied carbon by building element:

Structure (Sub and super structure)	→ Compare the embodied carbon options for sub and superstructure at an early stage to identify an optimum solution. → Typical bay studies for the horizontal and vertical grid should be conducted at concept stage for different material arrangements to determine the impact on the total embodied carbon for each framing arrangement. → A structural rationalisation study should be conducted to determine the impact on overall material quantity versus efficiency in construction/fabrication. → Reduce the weight of structure where possible through voids. → Maximum embodied carbon quantities should be specified for structural components. Targets can be achieved by cement replacement such as GGBS, low carbon concrete mix design, low carbon materials and using recycled/repurposed materials. → Structural frame should be considered to have a dual purpose, ie the structure could serve as a shading device rather than introducing additional shading elements to control solar gain. → Explore recycled sources of material.
Envelope (Facade and roof)	→ Carry out embodied carbon comparisons on typical construction bays during early design stages where decisions can be guided by benchmarks / data. → Remember that it is the hidden parts (for example metal secondary framing) of a build up that often contain the most embodied carbon. → Where metals are used, limit their use and ensure they can be removed and recycled at end of life.
Mechanical, Electrical and plumbing (MEP)	→ Avoid over-provision of plant - a detailed load assessment must be undertaken. → Typically, fewer and simpler systems will reduce embodied carbon. → Explore options for plant room locations which reduce duct runs. → Design for deconstruction and recycling as MEP is typically replaced 2-3 times during the lifespan of a building. → Specify refrigerants with low Global Warming Potential (i.e <150) and ensure refrigerant leakage is carefully considered in the whole life carbon analysis.
Finishes and Furniture Fixtures and equipment (FF&E)	→ Consider eliminating materials where not needed e.g. by exposing services. → Utilise self-finishing internal surfaces like timber. → Consider the cleaning and maintenance regime to be undertaken. → Ensure the fit out requirement is clearly understood to avoid FF&E to be replaced when the first tenant moved in. → Carefully compare products based on EPD data, recycled material and also avoidance of harmful chemicals like formaldehydes and VOCs. → Consider the replacement cycle and specify for longevity. → Choose products that do not rely on adhesives so fabrics or finishes can be replaced. → Be wary of trends that are likely to date and require early replacement.
Design for Manufacture and Assembly (DfMA)	→ Compare embodied carbon of DfMA solutions with standard solutions. → If DfMA is to be used, identify the elements by the end of RIBA Stage 2. Examples include, bathroom or WC pods, plant modules, facade elements, repeatable rooms, pre-fabricated structural elements including twin wall, columns and planks. → Engage the supply chain early. → Lightweight materials are preferable for transportation purpose. → Ensure the repeatable systems are designed for deconstruction.

Specific guidance relating to the potential reduction of embodied carbon on the Pope's Road development is given below, in line with recommendations outlined by the LETI 'Embodied Carbon Primer - Supplementary guidance to the Climate Emergency Design Guide'.

8.1.1 Structure

8.1.1.1 Steel

The World Steel Association reports that 51% of global steel is used for construction. The following recommendations are made to reduce the embodied carbon impact of steel across the project:

- To facilitate the re-use of materials, bolted connections and clamped fittings should be preferred to welded joints
- If practicable, the designer should specify standard connection details, including bolt sizes and the spacing of holes
- Easy and permanent access to connections should be guaranteed
- Where feasible, steel should be free from coatings or coverings that would prevent visual assessment
- The origin and properties of the component should be identified by bar-coding, e-tagging or stamping, and an inventory of products (material passport) shall be kept
- Long-span beams should be adopted to maintain flexibility of re-use in the future, allowing further cutting at a later stage
- The designer should rationalise and simplify the design, eliminating unnecessary variations and taking advantage of any opportunities provided by manufacturing off site, potentially using prefabricated solutions

The current design has re-considered the quantities and the following recommendations have been included.

The reinforcement steel has been reduced by 25% overall;

A larger percent of recycled steel (as much as 50%), has been considered in the reinforcement.

8.1.1.2 Concrete

Concrete accounts for circa 55.3% of the global warming potential (kgCO_2e) across the development, as analysed at this stage. The most used cement is Portland Cement, which represents over 90% of the embodied carbon of a typical concrete mix. The simplest way to reduce the embodied carbon of concrete is to reduce the amount of Portland Cement required by:

- Avoiding over-specification of strength grade. Concrete grade is often specified for durability rather than structural strength, but experience shows that cement content is often over-specified
- Use of cement replacements e.g. Fly ash or granulated ground blast furnace slag (GGBS)
- Increasing the recycled content of reinforcement steel (rebar) where possible

- Reduction of slab thickness by slimming off the excess. Moving from 265mm to 255mm could be structurally minimal but could save a considerable amount of material

The proposed design minimises the requirement for new foundations. The pile length has been reduced to 30m with a considerable reduction in the volume of concrete for both 900mm piles and 600mm piles.

8.1.2 Envelope

8.1.2.1 Aluminium

The production of primary aluminium requires a very high consumption of electricity, almost 10 times that of steel. Due to the energy intensive process, the embodied carbon is very high, especially if aluminium is used in large volumes. In addition to being very energy intensive, the most common method of refining aluminium from bauxite – the Bayer process – consumes large amounts of water. By contrast, aluminium is highly recyclable, with properties that do not deteriorate as the material is re-used. Worldwide, around 75% of all aluminium produced is still in use. Recycling uses only around 5% of the energy needed to produce primary aluminium. The recycled material supply chain is however not enough to cover the current demand.

The proposed façade of the Pope's Road development is formed of an aluminium curtain wall system.

The following recommendations are made to reduce the embodied carbon impact of aluminium across the project:

- Procure from a country with largely renewable energy infrastructure (e.g. Norway, Iceland)

- Reclaim as much aluminium as possible at the end-of-life of each product

- Aluminium should be treated as a high-value material and used sparingly, with re-use in mind

- Coatings should be avoided when unnecessary; environmental product declaration (EPD) coatings should be used wherever possible

- Coating (PPC) aluminium is easier to recycle at the end-of-life than anodized aluminium but needs more maintenance

8.1.2.2 Glass

Glass requires the use of sand and minerals, which are non-renewable natural raw materials. In some cases, double glazing can be more carbon efficient than triple glazing, as the carbon footprint derived from using a triple glazing system can be higher than the operational carbon saving over the anticipated lifetime of the building. The impact of the frame material of any glass windows is also key.

Testing of different glass materials and types was not undertaken as part of this LCA, due to the requirement to model the curtain wall system as a whole. Regardless, based on known understanding of the carbon impact of glazing materials, the following recommendations are also made to reduce its embodied carbon impact:

- Review the balance of benefits gained from specifying either double or triple glazing

- Adopting standard sizes of framing can ease the re-use of the product at the end-of-life stage

8.1.3 External works

When considering external works, key factors influencing embodied carbon are where materials been sourced and what maintenance is required.

The following fundamental recommendations are also made to reduce the embodied carbon impact the external works:

- Open areas can accommodate PV panels and plants to improve the overall carbon footprint of a development
- Many natural stone paving slabs on the market are thinner than equivalent concrete products due to their strength
- Specify different thicknesses according to the loadings of different areas (pedestrian / traffic)
- Use recycled materials (e.g., sleepers, timber, waste stone, glass)
- Use natural stone instead of concrete slabs
- Consider quarry location for transport, durability and specific maintenance requirements to be sure there is a carbon benefit
- Where applicable, for timber decking make sure the wood is certified and sustainably sourced
- Consider surface treatment for slip resistance and check if it must be treated to comply with fire regulations
- Maximize the amount of plant-life in amenity spaces (e.g. green walls) and unused areas such as roofs, balconies, façade setbacks and vertical walls, for additional insulation and carbon capture. Choose plants for pollinators to encourage self-seeding and integrate bug hotels, nesting places for birds and bats to support biodiversity

8.1.4 Building Services

Studies have shown that building services account for 2-27% of embodied carbon (11% on average). Many building services have a much shorter life span than the building itself, particularly the fit-out elements such as lighting and terminal units. Others, such as distribution systems and communal heating, typically have a long life and may in some cases outlast the building itself. Building services components are in the main made of metals and therefore have a large initial embodied carbon content, but also have high recycling rates.

There are many opportunities for design strategies that reduce both embodied and operational carbon. If it is possible to meet functional requirements without plant, then this is the best solution. If plant is needed, the following recommendations are made to reduce the embodied carbon impact of building services:

- Optimise provision and size by adopting load reduction measures, carrying out detailed load assessments, and carefully considering the requirements for flexibility and back-up
- Specify equipment with Low refrigerant GWP and leakage

- High thermal efficiency
- Long lifetime
- Light weight
- Materials with low embodied carbon
- Materials that can be demounted, disassembled and reused
- Ensure products and equipment are easily accessible for inspection, maintenance and replacement
- They should also be demountable and easy to disassemble in order to operate well for a longer period and be recycled or reused at their end-of-life
- Designers should ask for Environmental Product Declarations from suppliers
- In terms of recycling, pipework and ductwork are sheet metal and can be recycled for new pipes and ducts. In the air handling unit, the coils can be stripped down and so motors have copper wire to be recycled. Materials are recycled as much possible

8.1.5 Internal Finishes

Internal finishes are frequently replaced over the lifetime of a building and can require considerable maintenance and upkeep. While the overall quantity of this component is smaller compared to superstructure/substructure, the embodied carbon of maintenance and upkeep can be considerable across the whole life cycle, particularly in large buildings with significant wall/floor/ceiling area.

The following recommendations are also made to reduce the embodied carbon impact of internal finishes:

- Linoleum is a natural alternative to vinyl. When produced correctly it can help to sequester carbon and will decompose naturally at the end of its useful life. Vinyl is plastic based so will not decompose and will often end up in landfill
- Water based eco paints are readily available as alternatives to oil or water-based paints
- Cork can be harvested without felling trees and is a carbon store. As an internal finish, it offers a sense of warmth and acts as acoustic and thermal insulation, avoiding the need for additional finishes
- Bamboo is a fast-growing wood and offers a rapid form of carbon sequestration. It can be made into a range of products, including flooring. Consider though that bamboo usually needs to be laminated, and the impacts this may have on its future reuse
- Timber can be used internally in a range of ways
- Recycled products use no raw materials and are increasingly available. Plasterboard, kitchen tops and floor panels for example can all be specified as almost 100% recycled content

The internal finishes in this project have not been considered at this stage and further investigation will be carried out at a later stage.

8.1.6 Fixtures and Fittings

The following recommendations are made to reduce the embodied carbon impact of internal fixtures and fittings:

- Select FSC chain of custody certified timber and locally sourced natural materials
- Use materials with a high percentage of recycled content
- Compare material options by assessing maintenance requirements and embodied carbon
- Choose refurbished white goods where possible and white goods that have a good energy rating (A+++ European standard) with energy saving options
- Provide sockets with on/off switch for appliances so that users can avoid leaving electrical goods in standby mode
- Choose products and materials with a long-life cycle

8.1.7 Construction Processes

Opportunities to reduce the carbon impact of the construction process, including waste, transportation of materials, and site activities are also discussed below.

Waste

Waste contributes to whole life embodied carbon through:

- Manufacture and delivery of materials delivered to site and then not used
- Transportation of waste away from site
- Energy to recycle into other products
- Methane released if sent to landfill

Reducing waste saves money and reduces natural resource consumption and CO_2 emissions. Issues to consider reducing the embodied carbon due to waste include:

- Establish a waste policy and targets at the start of the project
- Design out waste
- Eliminate unnecessary elements
- Standardise sizes and details to reduce offcuts
- Reduce complexity to simplify construction process
- Evaluate the reuse and recycling opportunities of materials before specifying
- Maximise the reuse of demolished materials on site
- Consider off-site fabrication of buildings or elements to reduce waste
- Prepare and implement a Site Waste Management Plan

- Logistics & Materials Procurement
- Set up a logistics plan and utilise “just-in time” delivery
- Consider use of Construction Consolidation Centres
- Reduce the amount of surplus materials by ordering the correct amount at the right time
- Provide safe, secure and weatherproof materials storage areas to prevent damage and theft
- Establish take-back schemes with suppliers to collect surplus materials
- Engage with the supply chain to supply products and materials using minimal packaging, and segregate packaging for reuse

WRAP provides lots of guidance on how to achieve these. www.wrap.org.uk.

- Site Activities & Deliveries
- Opportunities to reduce CO_2 emissions associated with construction processes and associated transport have been identified as
- Energy efficient site accommodation
- Efficient use of construction plant
- Earlier connection to the electricity grid
- Good practice energy management on site
- Onsite measurement, monitoring and targeting
- Fuel efficient freight driving and renewable transport fuels
- Use of construction consolidation centres
- Renewable (low carbon) biofuels
- Reduce transport of waste
- Business travel fleet management
- Good practice energy management of corporate offices
- Reuse of formwork - it is assumed that the timber formwork is reused three times before being discarded. If is recommended that formwork on the project is reused five times. Adopting standardised detailing would enable formwork to be re-used multiple times and would allow for repetition of reinforcement. Reusable plastic formwork should be considered

A Circular Economy statement has been undertaken and accompanies the planning application. The proposed development has a Building Circularity score of 42%.

The calculated Building Circularity score represents the total materials circularity both in use of materials for the project as well as end of life handling. It is calculated as the average of Materials Recovered (representing use of circular materials in the

project) and Materials Returned (representing how effectively materials are returned, instead of disposed of or downgraded in value. The calculation is purely mass-based without material weighing.

The Building circularity score will be tested and monitored throughout the design process.

8.1.8 Design for Adaptability, Disassembly and Recyclability

When a building is demolished, most of the materials are discarded, and along with them the embodied energy is lost. If buildings were designed for adaptability and disassembly, rather than demolition, greater proportions of building materials could be salvaged for reuse. In such a scenario, embodied energy would be recovered along with the materials, thereby reducing the total energy requirements of the built environment.

The following recommendations are made in addition to those mentioned throughout previous sections of this report:

- Modular design – consider separating structural elements from functions that could be changed or moved as part of future adaptation, for example not enclosing lifts, stairs and toilets within shear walls, restricting where these could move in future fit-outs
- Consider where it may be possible to incorporate soft-spots or easily demountable structure for future alterations
- Consider spans, loads and structural grids that allow for changes and alternative uses
- Design connections to be visible and reversible
- Ensuring the building can be adapted for future changes in use
- Design in shading and openable windows for cooling where possible
- For brick facades, using lime mortar enables the bricks to be reclaimed and reused
- Use standard size products wherever possible rather than bespoke finishes
- Ideally the entire design team would be able to use the same platform (e.g. Revit) to develop and inform the design from different angles. BIM (Building Information Modelling) can be used to visualise, perform stress, deflection and other simulations in-house to avoid material intense methods. BIM is useful throughout the building life cycle to determine the best material choices, check manufacturability of part and mould designs to help avoid production delays, manufacturing defects or costly mistakes
- Using lightweight material can reduce transportation costs, provided the distances and mode of transportation are also considered
- Quality control to reduce the need for frequent repairs and maintenance

9.0 CONCLUSION

A Whole Life Cycle Assessment in accordance with the GLA requirements has been undertaken for the proposed development at Pope's Road. This has been done with the aim of recognising and encouraging measures to optimise construction product consumption efficiency, and the selection of products with a low environmental impact (including embodied carbon) over the life cycle of the building. The WLCA has been run for the entire building envelope, in line with the GLA requirements. This has been based on materials data provided by the project design team for applicable building elements required by the GLA methodology.

An options appraisal has been undertaken for the superstructure, substructure and hard landscaping elements. This has exemplified differing design scenarios potentially available to the project team to reduce the environmental impact of the proposed development.

The following recommendations were introduced and accepted:

- The pile length has been reduced to 30m with a considerable reduction in the volume of concrete for both 900mm piles and 600mm piles
- Reinforcement steel has been reduced by 25%
- An aluminium curtain wall system has been utilised over a steel curtain wall system

Table 8 below summarises the results of the WLCA;

	GLA Benchmark ($KgCO_2e/m^2$)	Aspirational GLA Benchmark ($KgCO_2e/m^2$)	Carbon ($KgCO_2e/m^2$)	Carbon Heros Rating ($KgCO_2e/m^2$)
Carbon to Complete (A1-A5)	900 – 1000	550-600	520	
Carbon Over Life (B-C excluding B6 & B7)	400 - 500	250-300	168	
WLCA - Current Electricity (A-D)			1696	
WLCA Future Electricity (A-D)			890	
Total Embodied Carbon (A1-A4, B4-B5, C1-C4)			658	E
Super Structure (A1-A4, B4-B5, C1-C4)			336	B
Sub Structure (A1-A4, B4-B5, C1-C4)			305	B

Table 8 - Results Summary

The Carbon to complete and Carbon Over Life for the Pope's Road development exceed GLA benchmarks.

The Whole Life Carbon using the future grid electricity has been shown to be 890 $KgCO_2e/m^2$ which is a 47.05% reduction from the current electricity grid.

The total embodied carbon for the whole development achieves a 'E' rating using the One Click Carbon Hero's Rating and both the Sub structure and Super structure achieve a rating of 'B'

Options for reducing the embodied carbon should be further explored during the Technical Design phase including the following;

- A larger percent of recycled steel (as much as 50%), in the steel sections
- The proposed ready-mix concrete including 50% Cement replacement with blast furnace slag (GGBS)
- Further analysis for hard landscaping and internal finishes

The above analysis suggests that the Pope's Road development has been designed in a carbon efficient manner and meets GLA Carbon benchmarks.

APPENDIX A

GLA WLC ASSESSMENT TEMPLATE MAY 2020