London Borough Southwark

LB Southwark Tustin Estate Whole Life Cycle Assessment

Report prepared by: Alex Waterfield

Report Approved by: Huw Blackwell

Date: 28/10/2020

Disclaimer

Whole Life Cycle Assessment

London Borough of Southwark

Prepared for:

Sophie Hall-Thompson
London Borough of Southwark
Regeneration Manager
Chief Executive's Office
London Borough of Southwark

Prepared by:

Alex Waterfield
Anthesis
Unit J. Taper Studios
175 Long Lane,
London
SE1 4GT

Report written by:

Alex Waterfield
+44 (0)7394 568 674
Alex.Waterfield@anthesisgroup.com

Email:

Website: www.anthesisgroup.com
Tel: 01865 250818
Company Registration: 08425819

Analysts:

Jonathan Pont

Quality Assurance

Report checked by:

Huw Blackwell, 01/10/2020

Report approved by:

Huw Blackwell, 01/10/2020
Approver +44 (0) 117 403 2654
Huw.Blackwell@anthesisgroup.com

Signature …………………………………………………………………

Version Control				
Version	Date	Author	Description of change	Approval
V1.0	17.08.2020	AW	Initial Draft for Comment	BL
V2.0	01.10.2020	AW	Client Comments Incorporated	HB
V3.0	28.10.2020	AW	Client Changes Incorporated	

Anthesis Consulting Group

Anthesis is the sustainability activator. We seek to make a significant contribution to a world which is more resilient and productive. We do this by working with cities, companies, and other organisations to drive sustainable performance. We develop financially driven sustainability strategies, underpinned by technical expertise and delivered by innovative collaborative teams across the world.

The company brings together 500 experts operating in 40 countries around the world and has offices in Andorra, Brazil, Canada, China, Colombia, Finland, France, Germany, Ireland, Italy, the Middle East, the Philippines, Spain, Sweden, the UK, and the US.

Executive summary

Anthesis were commissioned by the London Borough of Southwark to carry out an initial whole lifecycle carbon assessment, including operational (in-use) carbon and embodied (emissions during construction and demolition) carbon at Tustin Estate. This was to establish which course of development action is likely to have the highest carbon footprint at the Estate and to help the Council understand the difference in the carbon footprint between retaining homes and retrofitting energy-saving measures into the existing estate and rebuilding the development. This was compared against a baseline (or no-action) scenario.

Whereas a typical carbon assessment of a building involves looking at the carbon emitted through a building's energy use (e.g. Gas and electric usage), a whole life cycle assessment looks at the carbon footprint of the building at each stage of its development from sourcing the materials, to construction and maintenance and finally demolition and material disposal or recycling. By carrying out this assessment, it provides an estimate of the overall carbon footprint of the development and therefore factors in the impact of associated with demolition and redevelopment.

Five development scenarios were assessed in order to compare their whole life carbon footprint. The scenarios were chosen to align with the Tustin Estate redevelopment strategy and include a comparison with each of the proposed redevelopment options and a baseline/business as usual case. Within the redevelopment options, there was a split into a high embodied carbon build and a low embodied carbon build to enable a direct comparison and analysis of the reduction in whole life carbon by using alternative construction materials. In summary, all the scenarios explored were as follows:

- Scenario 0: Existing Estate. No investment in the estate. Business as usual.
- Scenario 1: Option 1. The existing estate but with connection to the South East London CHP (SELCHP) District Heating Network
- Scenario 2: Option 2. The existing estate with a connection to SELCHP and some new homes that help achieve zero carbon targets. Scenario 2a analyses embodied carbon using high embodied carbon construction materials and Scenario 2b with some lower embodied carbon materials
- Scenario 3: Option 3. The existing estate with connection to SELCHP and the refurbishment of some blocks and the demolition and rebuild of some blocks with new homes helping to achieve zero carbon targets. Two further sub-scenarios include Scenario 3a for high embodied carbon construction materials and Scenario 3b for low embodied carbon materials
- Scenario 4: Option 4. The demolition and rebuild of the estate with connection to SELCHP. Scenario 4a is the sub-scenario for high embodied carbon construction materials and Scenario 4b for low embodied carbon materials

The estimations have been developed from data provided by the Council and assumptions outlined in this report including any energy saving measures being introduced to existing housing and the build out of the proposed redevelopment scenarios. It is concluded that even under a low carbon full new build scenario (Scenario 4), the embodied carbon associated with the new construction is likely to outweigh the benefits derived from the lower operational carbon. The results show that the more the housing stock is retained and retrofitted with carbon saving measures, the less the total whole life carbon of the development. The embodied carbon of retrofitting is a fraction of the embodied carbon of a new build and the retained buildings still benefit from an operational carbon saving.

If redevelopment is pursued by the Council, either through retrofit of the existing estate or new build, it is recommended the choice of materials and processes within the building is scrutinised. This can be done through a combination of minimising how much material is used (for example, minimising concrete used within the structure) and acquiring recycled and naturally sourced materials with lower embodied carbon as an alternative where possible. It is recommended a detailed life cycle assessment is carried out at RIBA 3 of the building design to assess which low carbon materials can be used and feed into the specification and final Bill of Materials.

Table of contents

Introduction 7
Life Cycle Assessment Methodology 9
Data Collection and Analysis 11
Results 16
Conclusions 24
References 26
Appendix A 27

Introduction

The London Borough of Southwark have appointed Anthesis to conduct an initial whole Life Cycle Assessment of their existing Tustin Estate development. The appointment also includes an assessment of the Council's proposed new build options across the development.

The Council are proposing working with the London Energy Transformation Initiative (LETI) to ensure their own new housing programme plays an appropriate role in combatting climate change. The LB Southwark planning policy requires the construction of all new homes in the borough to achieve Net Zero Carbon (NZC), and the council has now declared a 'Climate emergency' with the goal of the borough being carbon neutral by 2030. However, in order to reach Net Zero Carbon, the Council must consider the emissions associated with their housing stock construction and building materials (embodied carbon), not just emissions through in-use consumption (operational carbon).

The aim of this report is to carry out a Whole Life Cycle Carbon assessment to quantify the emissions of the existing estate as it stands and compare against the embodied (emissions during construction, maintenance and demolition) and operational emissions of retrofitting energy efficiency measures into the current build. It will also be compared against the embodied and operational emissions of demolishing and building an entirely new estate, as well as mixtures of new build and retrofit carbon scenarios as per the Tustin Estate regeneration plans.

By exploring these different scenarios, the aim is to support the council in understanding the carbon performance of different development strategies and use this study to inform their stakeholder engagement.

This report shall include an explanation of how a lifecycle assessment is carried out, what data was supplied and the specific scenarios that were drawn from them and recommendations according to the assessment results. The figure below shows a summary of the areas analysed by a carbon life cycle assessment:

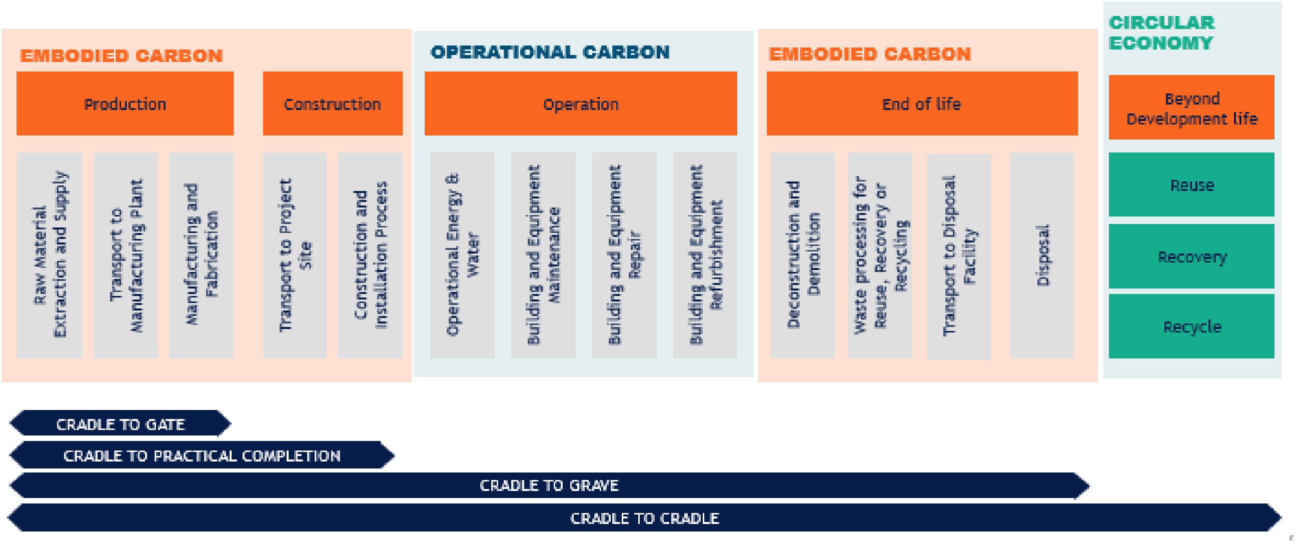

Figure 1: Life Cycle of a Building

Whereas a typical building energy assessment looks solely at the energy usage during the building's operational life (the blue section of the above figure), a life cycle assessment looks at all stages of a building's life. This includes the embodied carbon (shown in the orange sections in the above figure).

This can range from looking at:

- Cradle to Gate – Raw material extraction and manufacturing
- Cradle to Practical Completion – the stage above plus transport of the materials to site and the building construction
- Cradle to Grave – the stage above plus the building's operational use (including maintenance) and the final demolition of the building at the end of its life
- Cradle to Cradle – the stage above plus assessing what happens to the materials after demolition i.e. Whether it goes to landfill or if it is re-used or recycled

Each and every process in the above figure has a carbon footprint and by assessing the materials used within a building's construction, it is possible to establish how it was sourced and manufactured and therefore what its overall carbon footprint is likely to be. Thus, by looking at all the materials and processes within a building construction, a whole life cycle carbon footprint can be estimated.

Life Cycle Assessment Methodology

Life Cycle Assessments are key to assessing the environmental impact across a building's life. By carrying this out, you can estimate what the lifecycle emissions are from cradle to grave, and not just from in-use operation.

Within a building Life Cycle Assessment, the embodied emissions are assessed by looking at its carbon impact from across its life from material supply, to manufacture and fabrication and all the way to construction, installation, maintenance and finally, demolition. It also considers if the material has been recycled or undergone a low amount of processing. Embodied carbon within a building is minimised by reusing existing elements (e.g. structural frame), constructing from completely recycled materials and having processes involved in construction using solely renewable energy.

A Life Cycle Assessment is carried out in 4 stages:

1. Define Scope and Boundaries – what elements of the building are in scope for the assessment?
2. Estimate quantities of materials and processes – how much of each material within each building element being assessed is there? In the case of this study, it is estimated from the number of flats and the number of blocks planned for construction
3. Assess the carbon impact – what is the carbon content of each material? This is assessed by taking the material quantity and associating it with a carbon factor from the Inventory of Carbon and Energy (ICE)
4. Interpret the results – what impact does the material stock have?

For the purposes of this study within the redevelopment scenarios, a higher-carbon or conventional build will be assessed and compared against a lower-carbon build with conventional materials swapped out for lower embodied carbon alternatives.

The embodied carbon that is calculated can then be added to the operational (or in-use) carbon from the building stock over a nominal period of 30 years. This will estimate the Whole Life Carbon footprint of the building stock. The whole life carbon cycle can be visualised in the diagram below.

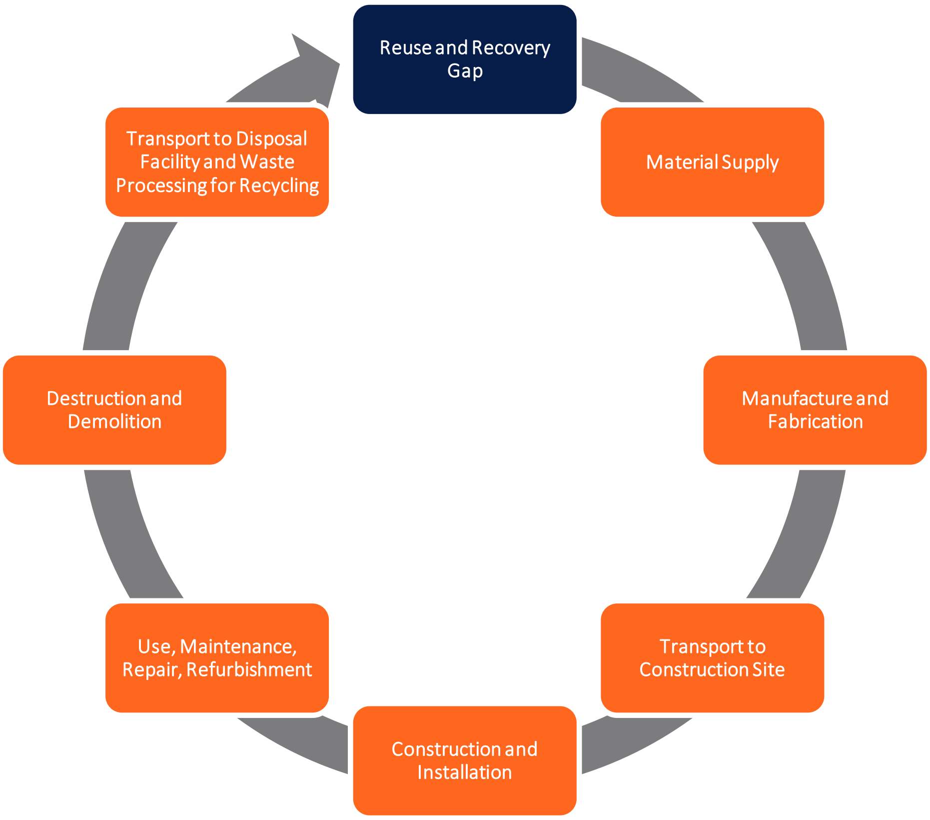

Figure 2 – Diagram Illustrating the Building Lifecycle

In a typical building lifecycle, there is traditionally a lot of energy and waste produced from each part of the steps shown in Figure 2. Within the industry, there needs to be a re-orientation to a circular economy. A circular economy is restorative or regenerative by intention and design and as well as minimising waste, includes a shift towards the use of renewable energy. At the end of a building's life, the demolition usually results in a lot of material waste which is not re-used or recycled. This means when a new building is produced, virgin materials need to be reproduced which uses more energy and emits more carbon. In order to address the climate emergency, the gap between demolition and material supply needs to be closed, meaning more materials that usually go to landfill at the end of a building's life can be re-used for a new-build.

A carbon lifecycle assessment analyses the nature of this process. New materials that have been processed from scratch e.g. Newly mined metals/minerals will have a higher carbon content than materials that have been recycled due to the amount of processing they have gone through. Through assessing all the materials that make up the building, the embodied carbon can be estimated.

Data Collection and Analysis

Data was provided by the Council to support this assessment. This data included details of the existing development which is as follows:

Table 1 – Unit Breakdown of the Existing Development

Block Name	Bedsits	1 Beds	2 Beds	3 Beds	4 Beds	Total
Ullswater	47					47
Bowness				34		34
Hillbeck	28	4				32
Kentmere	12	26				38
Manor Grove			25	11	13	49
Heversham	20		25	53		98
Total	107	30	50	98	13	**298**

A satellite image of the site is shown below. It is located off Old Kent Road in South Bermondsey, London. It shows a mixture of different existing builds of both residential and non-residential.

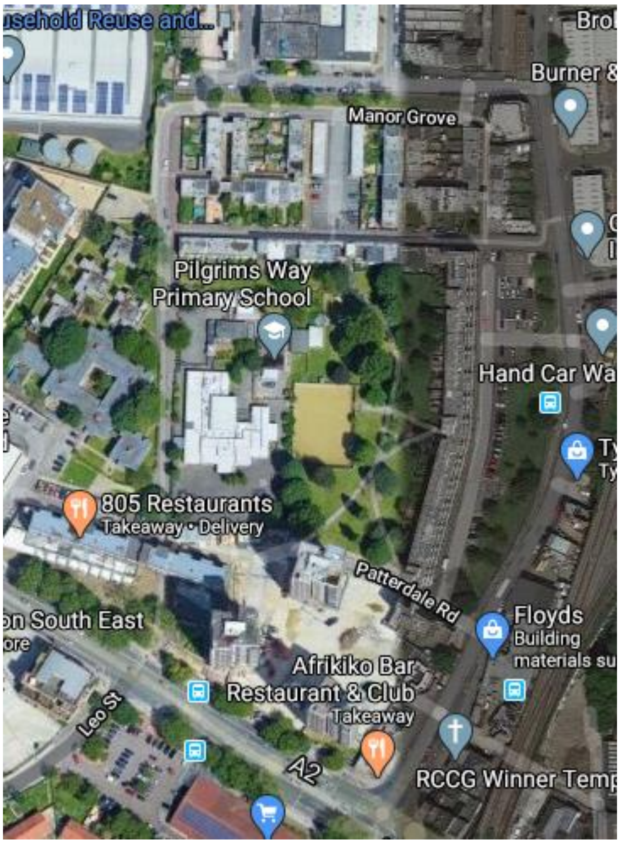

Figure 3 – Satellite Image of Tustin Estate

The Council also provided a 'Summary of Areas' document which gives a breakdown of different options for redeveloping the estate. As well as an option for retaining the estate (as per Table 1 above), 3 other options were provided for the estate redevelopment, each with different compositions of unit retention and rebuild. The breakdowns of these options are as follows:

Table 2: Unit Breakdown of the New Development (Option 2 from 'Summary of Areas' Spreadsheet)

Regeneration Type	**Bedsits**	**1 Beds**	**2 Beds**	**3 Beds**	**4 Beds**	**5 Beds**	**Total**
Retained Units	107	30	50	98	13	0	**298**
New/ Reprovided Units	4	39	33	17	5	0	**98**
Total	111	69	83	115	18	0	**396**

Table 3: Unit Breakdown of the New Development (Option 3 from 'Summary of Areas' Spreadsheet)

Regeneration Type	**Bedsits**	**1 Beds**	**2 Beds**	**3 Beds**	**4 Beds**	**5 Beds**	**Total**
Retained Units	18	0	44	87	12	0	**161**
New/ Reprovided Units	23	180	136	100	15	1	**455**
Total	41	180	180	187	27	1	**616**

Table 4: Unit Breakdown of the New Development (Option 4 from 'Summary of Areas' Spreadsheet))

Regeneration Type	**Bedsits**	**1 Beds**	**2 Beds**	**3 Beds**	**4 Beds**	**5 Beds**	**Total**
New/ Reprovided Units	39	315	230	177	29	6	**796**

The received spreadsheets also provide Gross areas of the proposed structures of new build blocks which were also used within the calculations.

It was agreed with the Client that the following scenarios for carbon lifecycle analysis would therefore be analysed:

- Scenario 0: Existing Estate. No investment in the estate. Business as usual.
- Scenario 1: Option 1. The existing estate but with connection to the South East London CHP (SELCHP) District Heating Network
- Scenario 2: Option 2. The existing estate with a connection to SELCHP and some new homes that help achieve zero carbon targets. Scenario 2a analyses embodied carbon using high embodied carbon construction materials and Scenario 2b with some lower embodied carbon materials
- Scenario 3: Option 3. The existing estate with connection to SELCHP and the refurbishment of some blocks and the demolition and rebuild of some blocks with new homes helping to achieve zero carbon targets. Two further sub-scenarios include Scenario 3a for high embodied carbon construction materials and Scenario 3b for low embodied carbon materials
- Scenario 4: Option 4. The demolition and rebuild of the estate with connection to SELCHP. Scenario 4a is the sub-scenario for high embodied carbon construction materials and Scenario 4b for low embodied carbon materials

The option numbers are as per the Tustin Estate redevelopment plans in the tables above. Within the existing estate, one of the blocks, Manor Grove, includes 49 units, 18 of which will be connecting to SELCHP within the carbon modelling and the other 31 will not be connecting. This is as per the Client’s existing intentions within the development. The methodology of modelling these scenarios will be explained further in the sections below.

Basis of Analysis

In order to ensure the analysis is carried out fairly and consistently across the 5no. scenarios (mentioned in the methodology below), a number of assumptions need to be made and justified. This establishes the basis of analysis and the life cycle assessment can be undertaken.

Firstly, across all scenarios, the operational carbon will be calculated over a period of 30 years. This ensures consistency across the scenarios and gives comparable figures for the operational carbon. If one or more scenarios had a different number of years in which the operational carbon was assessed, it would be more difficult to compare any kind of operational carbon improvement from any construction intervention.

Within the regeneration options, i.e. Scenarios 2 to 4, the retained units will undergo retrofitting of energy saving measures. 2no. of the energy saving measures from the received Tustin Estate Energy Analysis Report have been modelled within these scenarios. These are wall insulation and hot water cylinder jacket integration. These measures have been applied as an average number of retrofit measures across the retained estate. This is because these 2 measures were more favoured in the report, with the intention of applying them to most of the existing development. By applying them across the whole retained development, from a life cycle perspective, the aim is to show the impact these relatively small measures will have on the overall footprint.

The New Build or reprovided aspects of Scenarios 2 to 4 have each been modelled as 2no. different sub-scenarios. These include a high carbon ‘a’ scenario where materials are assumed to come from high carbon sources with very little recycled content and naturally sourced materials. There will also be a low carbon ‘b’ scenario where low carbon materials are used and applied primarily to the big-ticket items e.g. The building frame and the substructure. The aim of this is to show how making changes in the material choices within the new build aspects can have a significant impact on the embodied carbon footprint.

Within the embodied carbon analysis, M&E materials are not included in the scope due to the uncertainties around the energy strategy for the new build blocks. Moreover from an operational perspective, within the modelling, the split of electricity to heating within the energy demand has been kept consistent over the 30 year period with the main difference being the variation in carbon factors from the supplied electricity and heat.

Methodology

For the purposes of this assessment, 5 main scenarios have been explored:

- Scenario 0: Existing Estate. No investment in the estate. Business as usual.
- Scenario 1: Option 1. The existing estate but with connection to the South East London CHP (SELCHP) District Heating Network
- Scenario 2: Option 2. The existing estate with a connection to SELCHP and some new homes that help achieve zero carbon targets. Scenario 2a analyses embodied carbon using high embodied carbon construction materials and Scenario 2b with some lower embodied carbon materials
- Scenario 3: Option 3. The existing estate with connection to SELCHP and the refurbishment of some blocks and the demolition and rebuild of some blocks with new homes helping to achieve zero carbon targets. Two further sub-scenarios include Scenario 3a for high embodied carbon construction materials and Scenario 3b for low embodied carbon materials
- Scenario 4: Option 4. The demolition and rebuild of the estate with connection to SELCHP. Scenario 4a is the sub-scenario for high embodied carbon construction materials and Scenario 4b for low embodied carbon materials

For the Business as Usual approach, scenario 0, existing annual metered data for gas and electricity was used to model the carbon emissions over a 30-year lifetime. This provides a calculation for the operational carbon emissions of the buildings. It has been assumed there would be no embodied carbon emissions over this period as no construction intervention would be sought. This will provide a baseline where the other scenarios, which have construction intervention of some kind, can be compared against. For all Scenarios, the electricity carbon factor includes a forecasted reduction over the 30-year lifetime as it is anticipated that the national grid decarbonises.

Scenario 1 is as per Scenario 0 with the only difference being the existing estate is modelled as being connected to the SELCHP District Heating Network (DHN) for the supply of heating and hot water. Carbon factors for the connection to SELCHP have been sourced from the received Veolia 'Information for Developers' report (16 Jan 2020) including the anticipated decarbonisation of the network over the 30-year period. This connection excludes 31 units from Manor Grove which are anticipated to retain their existing heating system (this assumption applies to all the following scenarios as well).

Scenario 2 modelling is as per Option 2 of the Tustin Estate Redevelopment Plan, which includes reproviding 98 units and retaining all 298 existing units (a total of 396 units). The retained units will have 2no. energy saving measures retrofitted, as mentioned in the Basis of Analysis section above. This includes wall insulation and hot water cylinder insulation. An energy saving from integrating these measures was applied to the business-as-usual operational data and used to calculate the operational emissions over a 30-year period (inclusive of the SELCHP heat connection). The retrofit embodied carbon was calculated by calculating typical flat dimensions and therefore the volume of material required for new wall insulation installation and hot water cylinder insulation. These figures were then multiplied by the Inventory of Carbon and Energy Carbon factors for the proposed materials to provide the overall embodied carbon. This embodied carbon was then added to the 30-year operational carbon to provide an overall lifecycle carbon for the retained units.

For the Scenario 2 new/reprovided units, the proposed Gross plot areas of the new blocks and the new number of flat types have been used to estimate the quantities and types of materials used. The flat layouts provided were used to calculate typical dimensions of each aspect of the flats (e.g. Kitchen wall length, number of doors) for a typical 1 bed, 2 bed flat etc. These dimensions were then used to calculate the volume of different types of materials required per flat and then multiplied across the number of flats. For the external structure, the Gross Internal and External areas provided per block were used to calculate the external building area and height and therefore the volume of material required. The total volume of material could then be multiplied their respective carbon factors to provide an overall embodied carbon. 2no. different scenarios have been calculated for embodied carbon including a high-carbon conventional approach (Scenario 2a) and a lower-carbon approach (Scenario 2b) with recycled or low-processed materials used in place of the higher-carbon ones. Details of the alternative materials substituted for the low carbon scenario can be found in the results section of this report. The new build operational carbon is calculated using best practice Energy Use Intensity figures from the LETI Climate Emergency Primer. The split of electricity energy use per flat is then multiplied by the anticipated future grid carbon factors and the heating split is multiplied by the anticipated SELCHP factors. This is modelled over a 30-year period to provide the total operational new build carbon. The new build embodied carbon is then added to the operational carbon to provide the whole lifecycle carbon for the new build development.

For Scenario 3, the methodology for calculating the operational and embodied carbon is as per Scenario 2 with the main difference being the difference in the number of flats being retained and reprovided. The Scenario 4 methodology is also similar to Scenario 2, however as this scenario is all new-build (no house/flat retention), only the new build aspects of the methodology are used.

One of the key focus areas that will be established from the Life Cycle Assessment from an embodied carbon perspective is the dominant materials or component items that contribute the most emissions. It is likely that the top building elements that will have the highest share of embodied carbon are the piling, foundation, and the frame. By identifying these from the high carbon scenarios, this will give a focus on the materials to substitute in for the low carbon scenarios. At this stage of the Tustin estate development, a Life Cycle Assessment can give recommendations on the type of materials to focus on. However, at RIBA stage 3 of the building design, a fully-detailed whole life carbon assessment should be undertaken to identify the carbon emissions per element and the carbon reductions that can be achieved for each element. This can then be used to establish your final specification and Bill of Materials for the building construction.

Results

Overall Scenario Comparison

As the different scenarios being compared have different numbers of flats, the whole life carbon has been compared on a per-property and per-capita basis. The average capita has been calculated using the GLA Population Yield Calculator provided by the Council (see References).

Table 5: Whole Life Carbon Assessment Results

	Emissions per Property Over Lifetime (kgCO2e)	Emissions per Capita Over Lifetime (kgCO2e)
Scenario 0 – Existing Estate	57,246.52	23,530.30
Scenario 1 – Existing Estate with SELCHP Connection	19,554.79	8,037.69
Scenario 2a (High Embodied Carbon)	29,645.69	12,216.12
Scenario 2b (Low Embodied Carbon)	25,678.52	10,581.37
Scenario 3a (High Embodied Carbon)	52,405.09	20,853.70
Scenario 3b (Low Embodied Carbon)	41,526.84	16,524.89
Scenario 4a (High Embodied Carbon)	64,464.24	27,308.96
Scenario 4b (Low Embodied Carbon)	49,212.98	20,848.07

The analysis of this table goes into more detail below.

The below graph shows the results from the table above on a per property basis to give a visualisation of the difference in carbon between the different scenarios. It is split out into embodied and operational carbon to show the percentage of contribution between each.

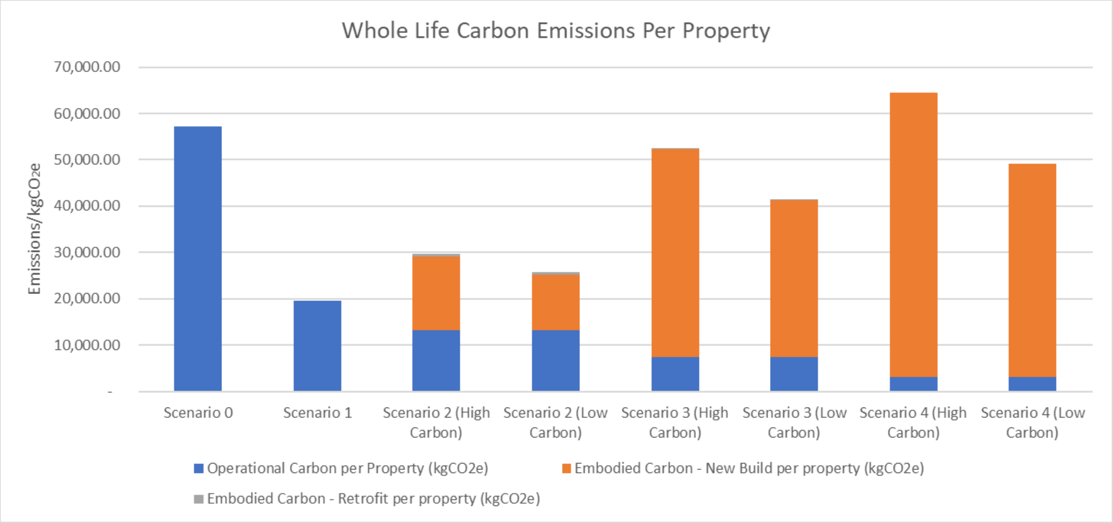

Figure 4

The below graph shows the same results on a per-capita basis.

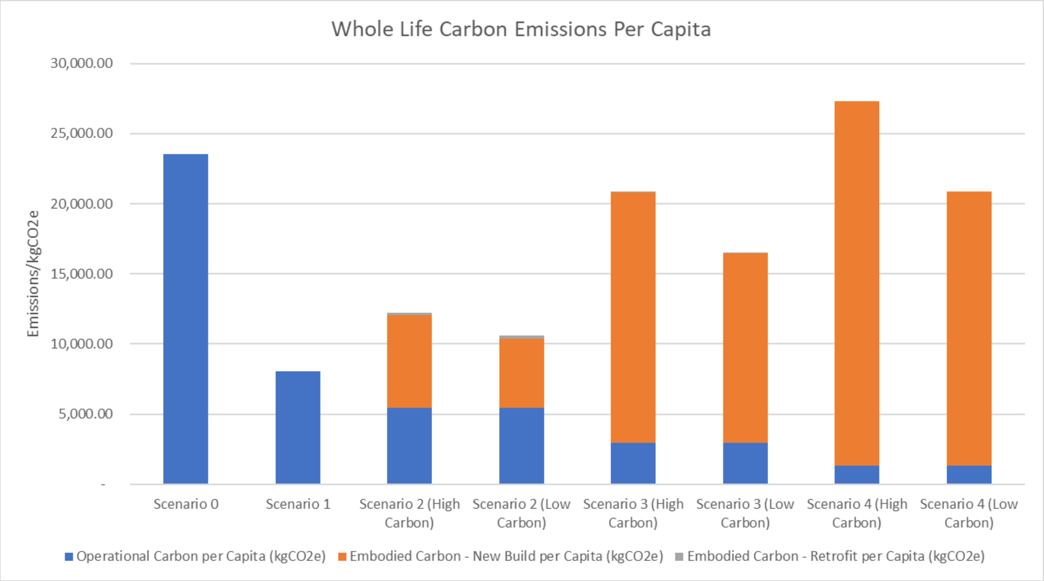

Figure 5

The graphs above show on both a per-capita and per-property basis, Scenario 1 has the lowest whole life carbon footprint. The addition of a SELCHP connection has a significant impact on the operational emissions due to its low carbon factor when compared to the use of gas in Scenario 0. The anticipated further reduction in the carbon factor for SELCHP during the lifecycle further adds to the benefit of the connection.

Another point to note is Scenario 2 also has a low whole life carbon when compared to the other scenarios. It can be seen from the figures above one of the reasons for this is the low volume of new build when compared to Scenarios 3 and 4. These scenarios benefit with a lower operational carbon from the more-efficient new builds, however this is outweighed significantly by the embodied carbon from building the new estate. Scenario 2 also has a high volume of house/flat retention and therefore retrofitting of energy efficiency measures. The embodied carbon for retrofitting is negligible when compared to the embodied carbon for the new build blocks, and the added energy efficiency allows Scenario 2 to also benefit from a further operational carbon saving. It highlights the fact that utilising as much of the existing estate structures as possible significantly reduces the embodied carbon.

A high-carbon conventional new-build shown in Scenario 4a has the highest carbon footprint per property and per capita. This scenario sees no retention of the existing buildings and has a complete rebuild. Even though the new builds will likely be more energy efficient and will therefore benefit from an operational carbon saving, the amount of material and processes involved with demolishing and rebuilding has a large impact on the overall footprint. However, the low-carbon new build Scenario 4b has a lower carbon footprint than the business-as-usual Scenario 0. This demonstrates the importance of constructing with less carbon-intensive materials as this scenario has a lower embodied carbon and still benefits from the low operational energy that comes with a new build.

As each of the scenarios has a different number of total units, another comparison to make is against each scenario when adding the whole life carbon likely to be emitted from building a new build estate elsewhere to meet the overall required housing demand. For the purposes of this analysis, it is assumed the total housing demand is 796 units from Option 4 of the Tustin Estate redevelopment plan. The whole life carbon added to each of the scenarios is equivalent to the extra new build units required to get to 796 units. For example, Scenario 1 currently has a total of 298 units, meaning an extra 498 new build units are required offsite to meet the 796-unit demand total. A graph of this analysis is shown below.

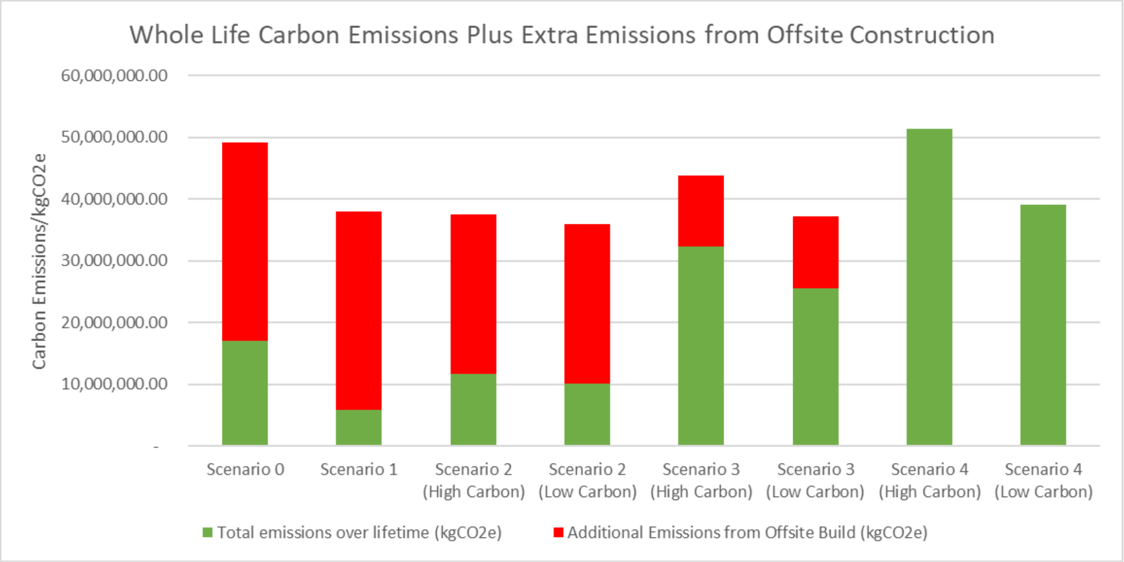

Figure 6

The above figure highlights further the benefit of retrofitting in the existing developments. For example, Scenario 2 requires an additional 400 units offsite to meet the 796-unit total. However, the carbon saving from retaining all the existing buildings in Tustin Estate significantly offsets the total whole life carbon despite the high number of new builds required offsite. Scenario 4 therefore still has the highest total whole life carbon as it does not utilise any of the existing structures in the estate. Scenario 3 retains some of the existing estate and due to the high number of units being built, less units are required offsite to meet the 796 total and therefore the offsite additional carbon is minimal.

The general trend therefore shows the more the existing buildings in the estate are retained, the less the total whole life carbon. The exception to this is Scenario 0 because no measures have been put in place to reduce the current operational carbon, which has had a significant effect on its whole life carbon.

Scenario 4: New Build Embodied Carbon Comparison

The following section describes a more detailed analysis of the embodied carbon of the new-build Scenario 4 to analyse the impact of substituting high embodied carbon materials with low carbon alternatives. Table 6 shows the material alternatives that were used to lower the embodied carbon between the high and low carbon scenarios. It is worth noting that this study only focuses on the dominant materials and components (the concrete structure for example) to demonstrate impact of using more sustainable materials. There are many different types of materials that can be used as alternatives for many different aspects of the buildings.

Below the table are 3no. graphs showing a breakdown of the embodied carbon associated with the High Carbon Buildout, the Low Carbon Buildout and the difference in Carbon between the 2 scenarios.

Table 6 – Low Embodied Carbon Measures Introduced in the New Build Scenario

Measure Number	High Carbon Buildout – Original Material Used	Low Carbon Buildout – Low Carbon Alternative Materials
1	Foundation includes both pilings and concrete slabs	Foundations made only with pilings, no concrete slabs
2	Market average insulation used	Rockwool insulation used
3	Concrete made using 13% GGBS (Ground-granulated Blast Furnace Slag) and virgin steel reinforcement	Concrete made from 73% GGBS (Ground-granulated Blast Furnace Slag) and using recycled steel for reinforcement
4	Conventionally sourced plywood and timber	Plywood and timber from sustainable sources

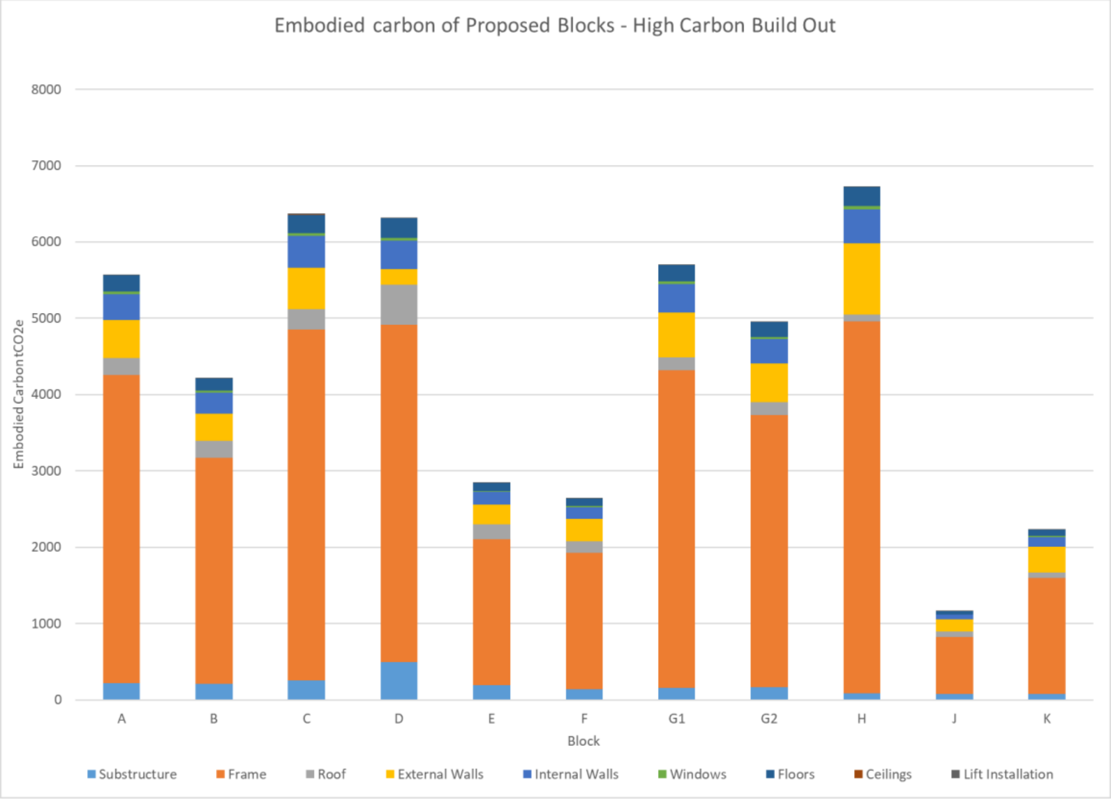

Figure 7

The figure above shows a visualisation of the amount of embodied carbon in each of the different components of the New Build option using high carbon materials and how it is distributed. It gives a representation of what the dominant components and materials are.

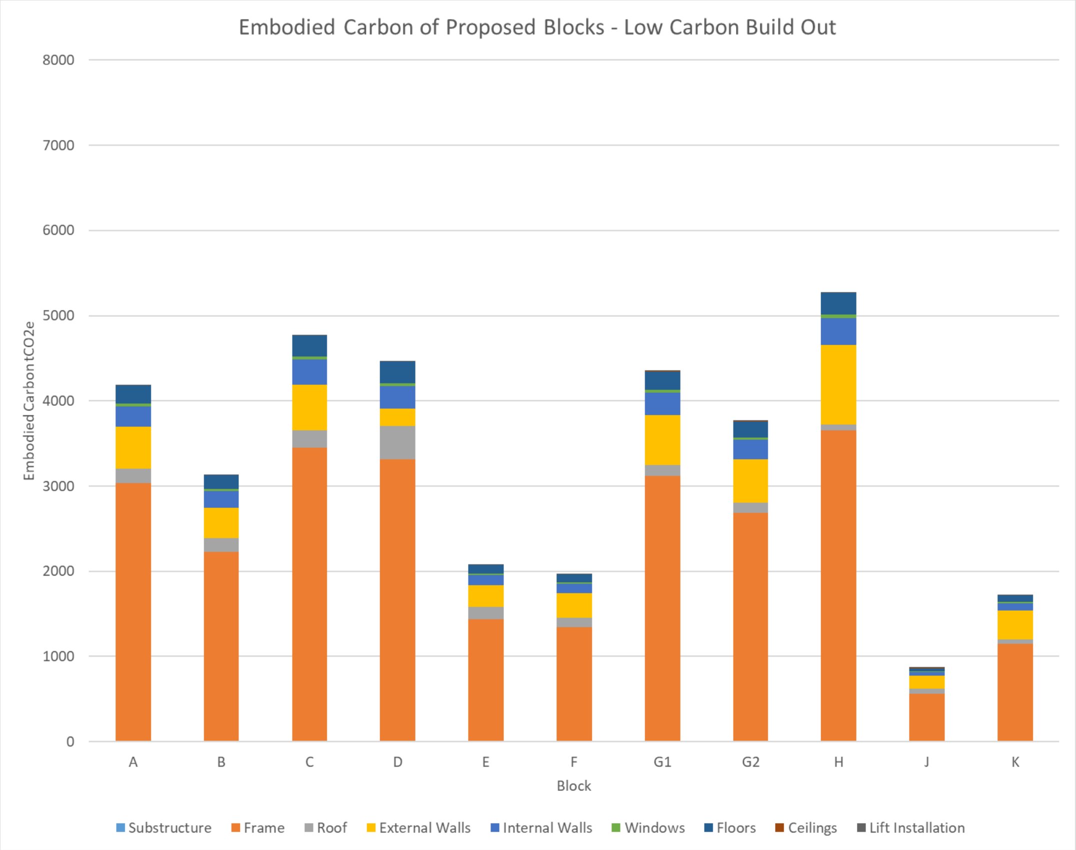

Figure 8

The figure above gives a visualisation of the distribution of embodied carbon across the New Build Option using low carbon materials.

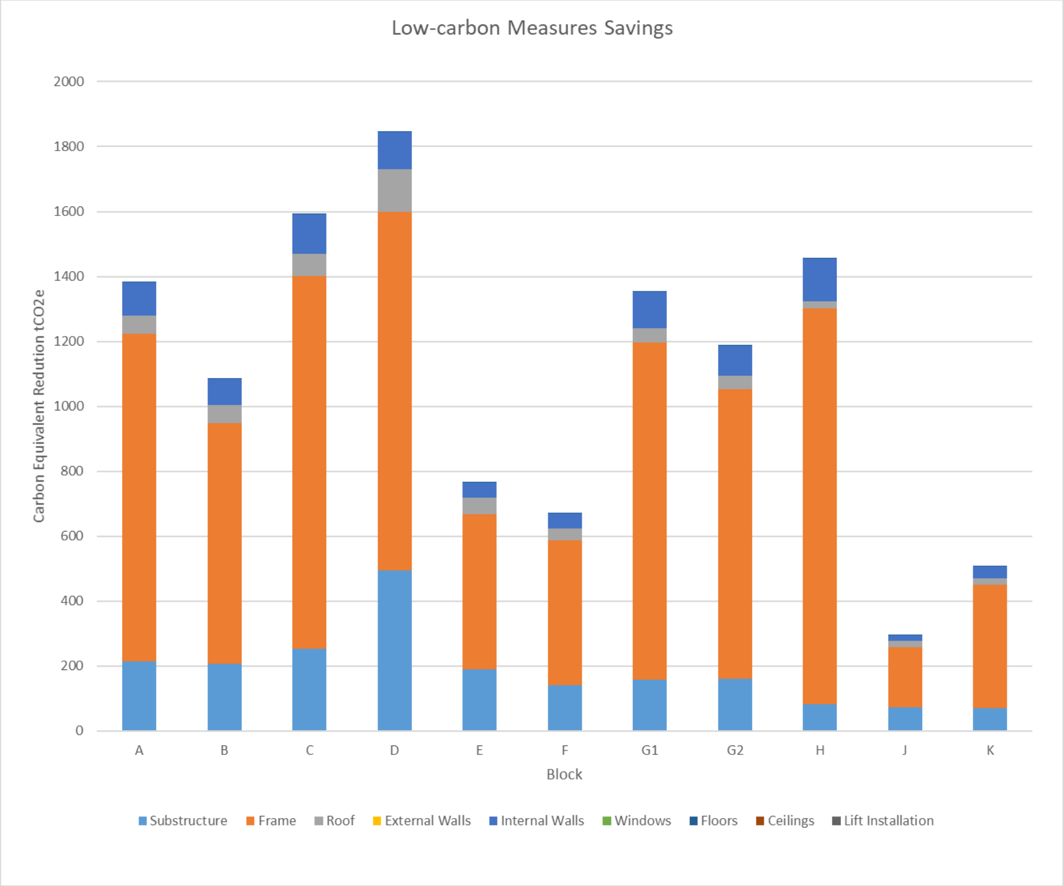

Figure 9

The figure above shows the difference in embodied carbon between the High Carbon New Build Scenario and the Low Carbon New Build Scenario. It shows where changing the materials has had the biggest impact on the embodied carbon of the buildings.

The above graphs show that by far the largest proportion of embodied carbon within the new build development would be from the frame, which makes up the main structure of the blocks, and in this scenario is primarily made from concrete. Compared to embodied carbon of the other materials that make up the building, it shows that minimising the use of concrete needs to be the highest priority. There has been a lot of discussion about replacing concrete structures with timber frames as a low carbon alternative in the market, however this is usually carried out in domestic houses where the structural loads are not as high. Within flat block complexes, concrete is still the favourable option to provide the necessary structural integrity. However, within these blocks, from an embodied carbon perspective the focus needs to be on minimising the amount of concrete required and sourcing a low carbon alternative, for example, blended cements using recycled material.

Within the 2 scenarios graphed-out, the alternative used has been GGBS concrete which utilises slag (a waste product from iron production processes). Compared to traditional concrete, which utilises cement, GGBS has a much lower carbon content per kg. Within the high-carbon build, the proportion of GGBS used is 13%, but in the low carbon build, the proportion is increased to 73%. Moreover, in the low carbon scenario, as an example the slab has been removed from the substructure assuming it is shown piling is able to provide sufficient ground stability (subject to approval from a structural engineer). Looking at Figure 9 (the difference in carbon between the 2 scenarios), it is evident that making these changes would result in a large reduction in the embodied carbon footprint of the new buildings.

Other material alternatives include sustainably sourced plywood and Rockwool used as a low carbon insulation. These have given a carbon reduction for the roof and internal wall elements of the buildings. The carbon reductions are not as high as the concrete measures introduced but still contribute to the overall reduction in building embodied carbon.

Conclusions

The council have been looking at different options for redeveloping Tustin Estate. Based on the Whole Lifecycle Analysis carried out in this report, the scenarios explored can be rated as follows (from least-carbon-intensive to most-carbon-intensive):

1. Scenario 1 – Existing Estate with SELCHP Connection
2. Scenario 2b (Low Embodied Carbon)
3. Scenario 2a (High Embodied Carbon)
4. Scenario 3b (Low Embodied Carbon)
5. Scenario 4b (Low Embodied Carbon)
6. Scenario 3a (High Embodied Carbon)
7. Scenario 0 – Existing Estate
8. Scenario 4a (High Embodied Carbon)

This study concludes that even when carrying out a new build with low carbon materials, the embodied carbon associated with the new construction outweighs the benefits derived from lower carbon operation. The options that include retention of the existing buildings had the lowest whole life carbon as it benefitted from utilising the existing building structure (and therefore minimising its embodied carbon) whilst also providing an operational carbon saving through the retrofit measures introduced. This can be seen in Figures 4 and 5 above. It shows the embodied carbon through retrofitting is very low but still gives an operational saving in scenarios 2 and 3. In comparison, Scenario 4, which is entirely new build, benefits from an operational carbon saving by being highly efficient but this is heavily outweighed by the embodied carbon emissions required for the new construction.

Rebuilding is an option to explore with caution when looking to address the climate emergency. Low carbon alternative materials should be explored further for use. Concrete would be the chosen material for many of the large component items within the new build make-up and has the highest carbon impact. So where possible, a low carbon alternative should be used in its place such as cement blended with recycled material. An alternative approach is to scrutinise where the material is being used within the building and where feasible, reduce or remove the use of it.

Where construction is carried out, to minimise embodied carbon as much material as possible should be from a recycled or natural source where there is minimal processing involved e.g. Natural wood, clay. Embodied carbon within a building is also minimised by having processes involved in construction using solely renewable energy. This paired with a lower operational energy demand will bring the council a step closer to reaching its net zero targets. Other advice for reducing embodied carbon includes:

- Target zero construction waste going to landfill
- Consider off site modular construction systems
- Design the building for long life and robustness
- Design the building for disassembly and the circular economy

It is recommended at RIBA stage 3 of the building design (where applicable for the intended redevelopment) to carry out a fully-detailed whole life carbon assessment to identify the carbon emissions per building element and the carbon reductions that can be achieved for each element by using alternative materials or processes. This can then be used to establish the final performance specification and Bill of Materials for the building construction/renovation.

References

‘Inventory of Carbon and Energy’ Database, V3.0, Nov 2019

‘SELCHP District Heating Network, Information for Developers’, V6, 16 Jan 2020, Veolia

‘Decentralised Energy Feasibility Study’, V1A, 28 Jan 2020, Anthesis

‘Green Book Supplementary Guidance: Valuation of Energy Use and Greenhouse Gas Emissions for Appraisal’, Data Table 1, March 2019, BEIS

‘LETI Climate Emergency Design Guide’, Jan 2020, London Energy Transformation Initiative

‘Spon’s Architects’ and Builders’ Price Book’, 140th Edition, 2015

‘GLA Population Yield Calculator’ Spreadsheet, V3.2, June 2019

Appendix A

Breakdown of the Embodied Carbon elements of the Scenarios 2 to 4 New Build, High Carbon and Low Carbon Options, split out per block.

Scenario 2a: High-Carbon New Build Estate													
		Carbon Content per Block											
Category	**Item**	**A**	**D**	**G**	**J**								**Units**
Substructure	Piles	1.76	1.76	1.76	1.76	-	-	-	-	-	-	-	tCO2e
Substructure	Concrete Basement Slab	34.70	85.79	105.41	102.19	-	-	-	-	-	-	-	tCO2e
Frame	Concrete Frame	720.72	709.35	1,632.89	1,108.50	-	-	-	-	-	-	-	tCO2e
Roof	Zinc	0.09	0.23	0.28	0.28	-	-	-	-	-	-	-	tCO2e
Roof	Plasterboard	0.01	0.02	0.03	0.03	-	-	-	-	-	-	-	tCO2e
Roof	Plywood	0.02	0.04	0.05	0.05	-	-	-	-	-	-	-	tCO2e
Roof	Insulation	0.46	1.14	1.41	1.36	-	-	-	-	-	-	-	tCO2e
Roof	Concrete Roofs	36.26	89.66	110.16	106.79	-	-	-	-	-	-	-	tCO2e
External Walls	Brickwork; single skin on brickwork angle support system; flashing; trims; weather board and insulation	95.22	37.43	124.48	95.33	-	-	-	-	-	-	-	tCO2e
External Walls	Solid cladding, aluminium panels, composite system with aluminium cladding on weather board within timber frame; insulation: flashings; accessories	123.86	48.69	161.91	123.99	-	-	-	-	-	-	-	tCO2e
Windows	Double glazed 4mm thick panels	6.06	6.26	15.00	7.17	-	-	-	-	-	-	-	tCO2e
Internal Walls	Concrete Walls	33.55	33.02	76.01	51.60	-	-	-	-	-	-	-	tCO2e
Internal Walls	Plasterboard wall	0.05	0.05	0.13	0.06	-	-	-	-	-	-	-	tCO2e
Lift Installation	Lifts	7.62	7.62	7.62	7.62	-	-	-	-	-	-	-	tCO2e
Internal Walls	Flush doors; non-fire rated; single leaf; solid core hardwood veneered; softwood frames; decorations; ironmongery	1.74	1.93	4.31	2.04	-	-	-	-	-	-	-	tCO2e
Internal Walls	Plasterboard dry lining; MF framing; to external facade; emulsion paint finish	0.26	0.27	0.67	0.32	-	-	-	-	-	-	-	tCO2e
Internal Walls	Ceramic tiles to kitchens	16.69	14.75	42.11	20.53	-	-	-	-	-	-	-	tCO2e
Internal Walls	Ceramic tiles to bathrooms	12.43	11.00	31.34	15.58	-	-	-	-	-	-	-	tCO2e
Floors	Floor finishes/ Sand cement screed; average 75 mm thick, steel fabric reinforcement, 100 thick insulation and separating layer	36.93	36.35	83.67	56.80	-	-	-	-	-	-	-	tCO2e
Floors	Insulation	0.21	0.88	0.63	0.61	-	-	-	-	-	-	-	tCO2e
Floors	Floor finishes/ Carpet	1.05	4.39	3.18	3.08	-	-	-	-	-	-	-	tCO2e
Ceilings	Plasterboard	0.05	0.05	0.11	0.08	-	-	-	-	-	-	-	tCO2e
Ceilings	Painting	0.32	0.32	0.73	0.49	-	-	-	-	-	-	-	tCO2e

Scenario 2b: Low-Carbon New Build Estate													
		Carbon Content per Block											
Category	**Item**	**A**	**D**	**G**	**J**								**Units**
Substructure	Piles	1.30	1.30	1.30	1.30	-	-	-	-	-	-	-	tCO2e
Substructure	Concrete Basement Slab	-	-	-	-	-	-	-	-	-	-	-	tCO2e
Frame	Concrete Frame	540.65	532.13	1,224.92	831.55	-	-	-	-	-	-	-	tCO2e
Roof	Zinc	0.09	0.23	0.28	0.28	-	-	-	-	-	-	-	tCO2e
Roof	Plasterboard	0.01	0.02	0.03	0.03	-	-	-	-	-	-	-	tCO2e
Roof	Plywood	- 0.02	- 0.06	- 0.07	- 0.07	-	-	-	-	-	-	-	tCO2e
Roof	Insulation	0.28	0.69	0.85	0.82	-	-	-	-	-	-	-	tCO2e
Roof	Concrete Roofs	27.20	67.26	82.64	80.11	-	-	-	-	-	-	-	tCO2e
External Walls	Brickwork; single skin on brickwork angle support system; flashing; trims; weather board and insulation	95.22	37.43	124.48	95.33	-	-	-	-	-	-	-	tCO2e
External Walls	Solid cladding, aluminium panels, composite system with aluminium cladding on weather board within timber frame; insulation: flashings; accessories	123.86	48.69	161.91	123.99	-	-	-	-	-	-	-	tCO2e
Windows	Double glazed 4mm thick panels	6.06	6.26	15.00	7.17	-	-	-	-	-	-	-	tCO2e
Internal Walls	Concrete Walls	24.80	24.41	56.18	38.14	-	-	-	-	-	-	-	tCO2e
Internal Walls	Plasterboard wall	0.05	0.05	0.13	0.06	-	-	-	-	-	-	-	tCO2e
Lift Installation	Lifts	7.62	7.62	7.62	7.62	-	-	-	-	-	-	-	tCO2e
Internal Walls	Flush doors; non-fire rated; single leaf; solid core	- 8.55	- 9.48	- 21.22	- 10.06	-	-	-	-	-	-	-	tCO2e
Internal Walls	Plasterboard dry lining; MF framing; to external facade; emulsion paint finish	0.26	0.27	0.67	0.32	-	-	-	-	-	-	-	tCO2e
Internal Walls	Ceramic tiles to kitchens	16.69	14.75	42.11	20.53	-	-	-	-	-	-	-	tCO2e
Internal Walls	Ceramic tiles to bathrooms	12.43	11.00	31.34	15.58	-	-	-	-	-	-	-	tCO2e
Floors	Floor finishes/ Sand cement screed; average 75 mm thick, steel fabric reinforcement, 100 thick insulation and separating layer	36.93	36.35	83.67	56.80	-	-	-	-	-	-	-	tCO2e
Floors	Insulation	0.13	0.53	0.38	0.37	-	-	-	-	-	-	-	tCO2e
Floors	Floor finishes/ Carpet	1.05	4.39	3.18	3.08	-	-	-	-	-	-	-	tCO2e
Ceilings	Plasterboard	0.05	0.05	0.11	0.08	-	-	-	-	-	-	-	tCO2e
Ceilings	Painting	0.32	0.32	0.73	0.49	-	-	-	-	-	-	-	tCO2e

Scenario 3a: High-Carbon New Build Estate

		Carbon Content per Block											
Category	**Item**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**K**		**Units**
Substructure	Piles	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	-	tCO2e
Substructure	Concrete Basement Slab	34.70	207.01	252.69	93.11	84.33	131.76	105.41	83.01	71.15	37.48	-	tCO2e
Frame	Concrete Frame	720.72	2,962.36	4,597.94	766.05	1,071.35	1,162.96	1,632.89	4,635.23	748.80	879.21	-	tCO2e
Roof	Zinc	0.09	0.56	0.68	0.25	0.23	0.36	0.28	0.22	0.19	0.10	-	tCO2e
Roof	Plasterboard	0.01	0.06	0.07	0.03	0.02	0.04	0.03	0.02	0.02	0.01	-	tCO2e
Roof	Plywood	0.02	0.10	0.13	0.05	0.04	0.07	0.05	0.04	0.04	0.02	-	tCO2e
Roof	Insulation	0.46	2.76	3.37	1.24	1.12	1.76	1.41	1.11	0.95	0.50	-	tCO2e
Roof	Concrete Roofs	36.26	216.34	264.08	97.31	88.13	137.70	110.16	86.75	74.36	39.17	-	tCO2e
External Walls	Brickwork; single skin on brickwork angle support system; flashing; trims; weather board and insulation	95.22	155.06	235.56	39.00	98.97	77.32	124.48	380.49	68.18	115.46	-	tCO2e
External Walls	Solid cladding, aluminium panels, composite system with aluminium cladding on weather board within timber frame; insulation: flashings; accessories	123.86	201.69	306.40	50.73	128.73	100.57	161.91	494.91	88.68	150.18	-	tCO2e
Windows	Double glazed 4mm thick panels	6.06	26.41	40.16	6.78	8.28	8.74	11.21	41.66	4.43	6.52	-	tCO2e
Internal Walls	Concrete Walls	33.55	137.90	214.04	35.66	49.87	54.14	76.01	215.77	34.86	40.93	-	tCO2e
Internal Walls	Plasterboard wall	0.05	0.22	0.32	0.05	0.07	0.07	0.09	0.36	0.04	0.05	-	tCO2e
Lift Installation	Lifts	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	-	tCO2e
Internal Walls	Flush doors; non-fire rated; single leaf; solid core hardwood veneered; softwood frames; decorations; ironmongery	1.74	7.54	11.45	2.10	2.38	2.51	3.31	12.07	1.34	1.89	-	tCO2e
Internal Walls	Plasterboard dry lining; MF framing; to external facade; emulsion paint finish	0.26	1.16	1.72	0.29	0.36	0.38	0.49	1.91	0.22	0.29	-	tCO2e
Internal Walls	Ceramic tiles to kitchens	16.69	72.60	109.73	15.88	22.70	23.83	27.23	116.05	13.36	18.70	-	tCO2e
Internal Walls	Ceramic tiles to bathrooms	12.43	54.28	82.95	11.88	16.84	17.67	19.99	86.78	9.48	13.86	-	tCO2e
Floors	Floor finishes/ Sand cement screed; average 75 mm thick, steel fabric reinforcement, 100 thick insulation and separating layer	36.93	151.80	235.61	39.25	54.90	59.59	83.67	237.52	38.37	45.05	-	tCO2e
Floors	Insulation	0.21	1.24	1.52	0.95	0.51	0.79	0.63	0.50	0.43	0.22	-	tCO2e
Floors	Floor finishes/ Carpet	1.05	6.24	7.61	4.77	2.54	3.97	3.18	2.50	2.14	1.13	-	tCO2e
Ceilings	Plasterboard	0.05	0.20	0.31	0.05	0.07	0.08	0.11	0.31	0.05	0.06	-	tCO2e
Ceilings	Painting	0.32	1.32	2.05	0.34	0.48	0.52	0.73	2.07	0.33	0.39	-	tCO2e

Scenario 3b: High-Carbon New Build Estate													
		Carbon Content per Block											
Category	**Item**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**K**		**Units**
Substructure	Piles	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	-	tCO2e
Substructure	Concrete Basement Slab	-	-	-	-	-	-	-	-	-	-	-	tCO2e
Frame	Concrete Frame	540.65	2,222.23	3,449.18	574.66	803.68	872.40	1,224.92	3,477.15	561.72	659.54	-	tCO2e
Roof	Zinc	0.09	0.56	0.68	0.25	0.23	0.36	0.28	0.22	0.19	0.10	-	tCO2e
Roof	Plasterboard	0.01	0.06	0.07	0.03	0.02	0.04	0.03	0.02	0.02	0.01	-	tCO2e
Roof	Plywood	- 0.02	- 0.14	- 0.17	- 0.06	- 0.06	- 0.09	- 0.07	- 0.06	- 0.05	- 0.03	-	tCO2e
Roof	Insulation	0.28	1.66	2.03	0.75	0.68	1.06	0.85	0.67	0.57	0.30	-	tCO2e
Roof	Concrete Roofs	27.20	162.29	198.10	73.00	66.11	103.30	82.64	65.08	55.78	29.38	-	tCO2e
External Walls	Brickwork; single skin on brickwork angle support system; flashing; trims; weather board and insulation	95.22	155.06	235.56	39.00	98.97	77.32	124.48	380.49	68.18	115.46	-	tCO2e
External Walls	Solid cladding, aluminium panels, composite system with aluminium cladding on weather board within timber frame; insulation: flashings; accessories	123.86	201.69	306.40	50.73	128.73	100.57	161.91	494.91	88.68	150.18	-	tCO2e
Windows	Double glazed 4mm thick panels	6.06	26.41	40.16	6.78	8.28	8.74	11.21	41.66	4.43	6.52	-	tCO2e
Internal Walls	Concrete Walls	24.80	101.92	158.19	26.36	36.86	40.01	56.18	159.48	25.76	30.25	-	tCO2e
Internal Walls	Plasterboard wall	0.05	0.22	0.32	0.05	0.07	0.07	0.09	0.36	0.04	0.05	-	tCO2e
Lift Installation	Lifts	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	-	tCO2e
Internal Walls	Flush doors; non-fire rated; single leaf; solid core	- 8.55	- 37.09	- 56.33	- 10.35	- 11.68	- 12.32	- 16.28	- 59.40	- 6.57	- 9.30	-	tCO2e
Internal Walls	Plasterboard dry lining; MF framing; to external facade; emulsion paint finish	0.26	1.16	1.72	0.29	0.36	0.38	0.49	1.91	0.22	0.29	-	tCO2e
Internal Walls	Ceramic tiles to kitchens	16.69	72.60	109.73	15.88	22.70	23.83	27.23	116.05	13.36	18.70	-	tCO2e
Internal Walls	Ceramic tiles to bathrooms	12.43	54.28	82.95	11.88	16.84	17.67	19.99	86.78	9.48	13.86	-	tCO2e
Floors	Floor finishes/ Sand cement screed; average 75 mm thick, steel fabric reinforcement, 100 thick insulation and separating layer	36.93	151.80	235.61	39.25	54.90	59.59	83.67	237.52	38.37	45.05	-	tCO2e
Floors	Insulation	0.13	0.75	0.91	0.57	0.30	0.48	0.38	0.30	0.26	0.14	-	tCO2e
Floors	Floor finishes/ Carpet	1.05	6.24	7.61	4.77	2.54	3.97	3.18	2.50	2.14	1.13	-	tCO2e
Ceilings	Plasterboard	0.05	0.20	0.31	0.05	0.07	0.08	0.11	0.31	0.05	0.06	-	tCO2e
Ceilings	Painting	0.32	1.32	2.05	0.34	0.48	0.52	0.73	2.07	0.33	0.39	-	tCO2e

Scenario 4a: High-Carbon New Build Estate													
		Carbon Content per Block											
Category	**Item**	**A**	**B**	**C**	**D**	**E**	**F**	**G1**	**G2**	**H**	**J**	**K**	**Units**
Substructure	Piles	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	tCO2e
Substructure	Concrete Basement Slab	212.57	207.01	252.69	494.54	189.30	139.52	158.70	158.99	83.01	71.15	70.13	tCO2e
Frame	Concrete Frame	4,042.67	2,962.36	4,597.94	4,414.82	1,909.87	1,784.74	4,156.57	3,573.69	4,874.47	748.80	1,524.64	tCO2e
Roof	Zinc	0.57	0.56	0.68	1.34	0.51	0.38	0.43	0.43	0.22	0.19	0.19	tCO2e
Roof	Plasterboard	0.06	0.06	0.07	0.13	0.05	0.04	0.04	0.04	0.02	0.02	0.02	tCO2e
Roof	Plywood	0.11	0.10	0.13	0.25	0.09	0.07	0.08	0.08	0.04	0.04	0.04	tCO2e
Roof	Insulation	2.84	2.76	3.37	6.60	2.53	1.86	2.12	2.12	1.11	0.95	0.94	tCO2e
Roof	Concrete Roofs	222.16	216.34	264.08	516.83	197.83	145.81	165.85	166.16	86.75	74.36	73.29	tCO2e
External Walls	Brickwork; single skin on brickwork angle support system; flashing; trims; weather board and insulation	216.05	155.06	235.56	89.87	111.21	127.30	254.56	220.82	405.03	68.18	146.65	tCO2e
External Walls	Solid cladding, aluminium panels, composite system with aluminium cladding on weather board within timber frame; insulation: flashings; accessories	281.03	201.69	306.40	116.90	144.65	165.58	331.11	287.23	526.84	88.68	190.76	tCO2e
Windows	Double glazed 4mm thick panels	30.97	26.60	39.19	35.08	14.87	14.15	35.47	28.88	42.05	4.43	10.43	tCO2e
Internal Walls	Concrete Walls	188.19	137.90	214.04	205.51	88.90	83.08	193.49	166.36	226.91	34.86	70.97	tCO2e
Internal Walls	Plasterboard wall	0.25	0.22	0.33	0.27	0.12	0.12	0.30	0.24	0.36	0.04	0.09	tCO2e
Lift Installation	Lifts	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	tCO2e
Internal Walls	Flush doors; non-fire rated; single leaf; solid core hardwood veneered; softwood frames; decorations; ironmongery	9.00	7.65	11.33	10.24	4.27	4.05	10.49	8.32	12.13	1.34	3.03	tCO2e
Internal Walls	Plasterboard dry lining; MF framing; to external facade; emulsion paint finish	1.32	1.19	1.74	1.44	0.66	0.63	1.63	1.30	1.92	0.22	0.47	tCO2e
Internal Walls	Ceramic tiles to kitchens	79.00	74.24	106.56	87.75	41.04	39.06	96.50	81.66	117.67	13.36	29.93	tCO2e
Internal Walls	Ceramic tiles to bathrooms	58.92	55.19	79.16	67.12	30.47	29.09	70.99	60.77	88.70	9.48	22.17	tCO2e
Floors	Floor finishes/ Sand cement screed; average 75 mm thick, steel fabric reinforcement, 100 thick insulation and separating layer	207.16	151.80	235.61	226.23	97.87	91.45	212.99	183.12	249.78	38.37	78.13	tCO2e
Floors	Insulation	1.28	1.24	1.52	5.05	1.14	0.84	0.95	0.95	0.50	0.43	0.42	tCO2e
Floors	Floor finishes/ Carpet	6.40	6.24	7.61	25.32	5.70	4.20	4.78	4.79	2.50	2.14	2.11	tCO2e
Ceilings	Plasterboard	0.27	0.20	0.31	0.30	0.13	0.12	0.28	0.24	0.33	0.05	0.10	tCO2e
Ceilings	Painting	1.80	1.32	2.05	1.97	0.85	0.80	1.85	1.59	2.17	0.33	0.68	tCO2e

Scenario 4b: Low-Carbon New Build Estate

		Carbon Content per Block											
Category	**Item**	**A**	**B**	**C**	**D**	**E**	**F**	**G1**	**G2**	**H**	**J**	**K**	**Units**
Substructure	Piles	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	tCO2e
Substructure	Concrete Basement Slab	-	-	-	-	-	-	-	-	-	-	-	tCO2e
Frame	Concrete Frame	3,032.64	2,222.23	3,449.18	3,311.81	1,432.70	1,338.83	3,118.08	2,680.83	3,656.61	561.72	1,143.72	tCO2e
Roof	Zinc	0.57	0.56	0.68	1.34	0.51	0.38	0.43	0.43	0.22	0.19	0.19	tCO2e
Roof	Plasterboard	0.06	0.06	0.07	0.13	0.05	0.04	0.04	0.04	0.02	0.02	0.02	tCO2e
Roof	Plywood	- 0.15	- 0.14	- 0.17	- 0.34	- 0.13	- 0.10	- 0.11	- 0.11	- 0.06	- 0.05	- 0.05	tCO2e
Roof	Insulation	1.71	1.66	2.03	3.97	1.52	1.12	1.27	1.28	0.67	0.57	0.56	tCO2e
Roof	Concrete Roofs	166.65	162.29	198.10	387.71	148.40	109.38	124.42	124.64	65.08	55.78	54.98	tCO2e
External Walls	Brickwork; single skin on brickwork angle support system; flashing; trims; weather board and insulation	216.05	155.06	235.56	89.87	111.21	127.30	254.56	220.82	405.03	68.18	146.65	tCO2e
External Walls	Solid cladding, aluminium panels, composite system with aluminium cladding on weather board within timber frame; insulation: flashings; accessories	281.03	201.69	306.40	116.90	144.65	165.58	331.11	287.23	526.84	88.68	190.76	tCO2e
Windows	Double glazed 4mm thick panels	30.97	26.60	39.19	35.08	14.87	14.15	35.47	28.88	42.05	4.43	10.43	tCO2e
Internal Walls	Concrete Walls	139.09	101.92	158.19	151.89	65.71	61.40	143.01	122.95	167.71	25.76	52.46	tCO2e
Internal Walls	Plasterboard wall	0.25	0.22	0.33	0.27	0.12	0.12	0.30	0.24	0.36	0.04	0.09	tCO2e
Lift Installation	Lifts	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	tCO2e
Internal Walls	Flush doors; non-fire rated; single leaf; solid core	- 44.28	- 37.61	- 55.74	- 50.39	- 20.99	- 19.94	- 51.59	- 40.93	- 59.69	- 6.57	- 14.88	tCO2e
Internal Walls	Plasterboard dry lining; MF framing; to external facade; emulsion paint finish	1.32	1.19	1.74	1.44	0.66	0.63	1.63	1.30	1.92	0.22	0.47	tCO2e
Internal Walls	Ceramic tiles to kitchens	79.00	74.24	106.56	87.75	41.04	39.06	96.50	81.66	117.67	13.36	29.93	tCO2e
Internal Walls	Ceramic tiles to bathrooms	58.92	55.19	79.16	67.12	30.47	29.09	70.99	60.77	88.70	9.48	22.17	tCO2e
Floors	Floor finishes/ Sand cement screed; average 75 mm thick, steel fabric reinforcement, 100 thick insulation and separating layer	207.16	151.80	235.61	226.23	97.87	91.45	212.99	183.12	249.78	38.37	78.13	tCO2e
Floors	Insulation	0.77	0.75	0.91	3.04	0.68	0.50	0.57	0.57	0.30	0.26	0.25	tCO2e
Floors	Floor finishes/ Carpet	6.40	6.24	7.61	25.32	5.70	4.20	4.78	4.79	2.50	2.14	2.11	tCO2e
Ceilings	Plasterboard	0.27	0.20	0.31	0.30	0.13	0.12	0.28	0.24	0.33	0.05	0.10	tCO2e
Ceilings	Painting	1.80	1.32	2.05	1.97	0.85	0.80	1.85	1.59	2.17	0.33	0.68	tCO2e