## ENCLOSURE 2: WHOLE LIFECYLE CARBON ASSESSMENT PREPARED BY BPC CONSULTING ENGINEERS

# BUILDING PERFORMANCE CONSULTING

## City Quay

## Whole Lifecycle Carbon Assessment

Project Ref: 20515

Client: Ventaway Ltd.

Date: 05/01/2024

BPC ENGINEERS

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| P1-01 | Draft: Issue for comment | 02/01/2023 | GB | John Gleeson<br>CEng MIEI, CMVP (AEE) |
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# Executive Summary

This report provides information on the whole life-cycle carbon assessment performed for the demolition of the existing disused former City Arts Centre Building and construction of a 24 storey mixed use building containing an arts centre, office and café accommodation, and exhibition performance space on a parcel of land which includes 1-4 City Quay, Dublin 2, 23-25 Moss Street, Dublin 2 and 5 City Quay, Dublin 2.

Dublin City Council (DCC) development plan acknowledges that good quality, higher density developments can make a positive contribution to the evolving urban form and structure of the city and can help to achieve sustainable land use and movement patterns. Ventaway Ltd. objectives align to DCC's objective to provide for increased density in a sustainable manner whilst ensuring the highest standards of design as well as the protection of existing amenities and the natural and historical assets of the city.

This report responds to sections of Appendix 3 criteria of the Dublin City Development Plan 2022-2028, specifically the following:

"15.7.1 Re-use of Existing Buildings

Where development proposal comprises of existing buildings on the site, applicants are encouraged to reuse and repurpose the buildings for integration within the scheme, where possible in accordance with Policy CA6 and CA7. Where demolition is proposed, the applicant must submit a demolition justification report to set out the rational for the demolition having regard to the 'embodied carbon' of existing structures and demonstrate that all options other than demolition, such as refurbishment, extension or retrofitting are not possible; as well as the additional use of resources and energy arising from new construction relative to the reuse of existing structures. Existing building materials should be incorporated and utilised in the new design proposals where feasible and a clear strategy for the reuse and disposal of the materials should be included where demolition is proposed."

CA6 of the Dublin City Development Plan 2022-2028 states:

"Retrofitting and Reuse of Existing Buildings

To promote and support the retrofitting and reuse of existing buildings rather than their demolition and reconstruction, where possible. See Section 15.7.1 Re-use of Existing Buildings in Chapter 15 Development Standards".

CA7 of the Dublin City Development Plan 2022-2028 states:

"Energy Efficiency in Existing Buildings

To support high levels of energy conservation, energy efficiency and the use of renewable energy sources in existing buildings, including retro-fitting of appropriate energy efficiency measures in the existing building stock, and to actively retrofit Dublin Council housing stock to a B2 Building Energy Rating (BER) in line with the government's Housing for All Plan retrofit targets for 2030."

Our rational and justification for demolition is the existing building is at end of life, is currently derelict and the refurbishing of it would not be in line with the current Dublin City Development Plan.

As part of the application, a Demolition Justification Report was prepared by PMEP which stated the following:

"Commentary on Embodied Energy

6.10 There is embodied energy and carbon in any existing building. This particular building has relatively poor fabric and consequent heat loss and, while it is possible to mitigate this through retro-fitting insulation, it will never reach nZEB standards and continuing to heat or cool the existing building over time will result in significantly more energy being used and consequently more carbon than would be the case if it was replaced.

6.11 Much of the demolished material with its embedded carbon can be crushed and reused elsewhere as fill in civil engineering projects"

If this planning application is granted a comprehensive demolition plan would be created which outlines the sequence of work, safety measures, and environmental considerations. This plan would include waste management strategies and recycling efforts of all existing materials.

The analysis assessed the whole life-cycle carbon for the proposed development. Table 1 shows the embodied carbon totals.

*Table 1 Embodied Carbon results summary*

| Building | Embodied Carbon | |
|---|---|---|
| | $kgCO_2e$ | $kgCO_2e/m^2$ |
| City Quay – New Build | 25,331,776 | 705 |

The embodied carbon emissions are calculated in line with EN 15978 for the carbon life-cycle stages A1-A5, B1-B5 and C1-C4 using Life-Cycle Analysis (LCA) software.

The estimated embodied carbon emissions associated with the construction of the new building are 705 $kgCO_2e/m^2$, which is line with the average value for the Western Europe office buildings[1]. The upfront embodied carbon emissions for stages A1-A5 are 468 $kgCO_2e/m^2$ for the new building.

Life-cycle stages A1-A3 (Materials/Product Stage) represent 66% of the total life-cycle embodied carbon for the new building. This highlights the importance of selecting low embodied carbon material where possible. Life-cycle stages B4-B5 (repair and replacement) are the next biggest contributors (by LCA stage) and are an important consideration when determining which elements to target first with respect to reducing embodied carbon (EC). For example, the up-front EC (stages A1-A3) associated with rebar is about 13.7% of the total EC (for these stages) and the raised access flooring accounts for about 9.1% of EC for the same stages. However, when the whole life-cycle (stages A-C), including replacement is considered, the raised access floor constitutes about 17% of the overall EC while the rebar falls to 9.3%. Therefore, when assessing which building elements to target first, it is important to consider the whole building lifecycle.

While the embodied carbon of the elements of the proposed building have been considered thus far, it is proposed to target the following elements/resources which have the highest life-cycle embodied carbon during the detailed design phase of the project:

- Ready-mix concrete for external walls and floors:
    - Increasing GGBS % (30% currently assumed.)
- Raised flooring systems:
    - Alternative system types, e.g. calcium sulphate raised floors.
- Structural steel and steel profiles :
    - Increasing recycled content (20% currently assumed.)
- HVAC components and equipment:
    - Reducing amount of equipment/material.

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[1] Based on OneClick LCA Carbon Heroes Benchmarking.

    - Considering equipment EC when specifying equipment and selecting lower EC options where possible. (Whole lifecycle needs to be considered including operational energy.)
    - Particular attention to be paid to AHUs where units may be custom and may offer more flexibility with regard to specifications compared to other equipment.
- Glass façade including frames:
    - Reducing amount of material, e.g. framing %.
    - Product selection. Recycled aluminium consumes roughly 10% of the energy of virgin sourced material so choosing products that use recycled aluminium can reduce EC significantly.

The whole life-cycle carbon emissions were calculated by adding the embodied carbon emissions and the operational carbon emissions over the building life-cycle, which is assumed to be 60 years. A number of scenarios were assessed for different operational energy figures. The operational carbon for the new building was calculated based on three different annual operational energy figures: 150 kWh/m$^2$, 100 kWh/m$^2$ and 75 kWh/m$^2$. Additionally, the operational energy/carbon calculations considered two different grid decarbonisation scenarios:

1. **Estimated grid decarbonisation**: Projected electricity grid decarbonisation based on historical average decarbonisation rate.
2. **Slower decarbonisation:** Decarbonisation of the grid slower than projected in option 1 (approximately 50% slower over a 60 year period.)

A summary of the whole life-cycle carbon results accounting for the projected decarbonisation of electricity grid is shown in Table 2 and Figure 1.

*Table 2: Whole Life Cycle Carbon Emissions - Accounting for grid decarbonisation*

| | Whole Life Cycle Carbon Emissions (kg$CO_2$) |
|---|---|
| New Building Operational Energy (kWh/m$^2$) | New Build |
| 150 | 48,378,951 |
| 100 | 43,189,024 |
| 75 | 40,594,061 |

This assessment is the starting point to assess embodied carbon reduction strategies such as alternative low carbon materials and assemblies. The embodied carbon reduction strategies will be challenged further during the detailed design phase of the project. However, the results show that the building is in line with the existing benchmarks for whole life-cycle carbon.

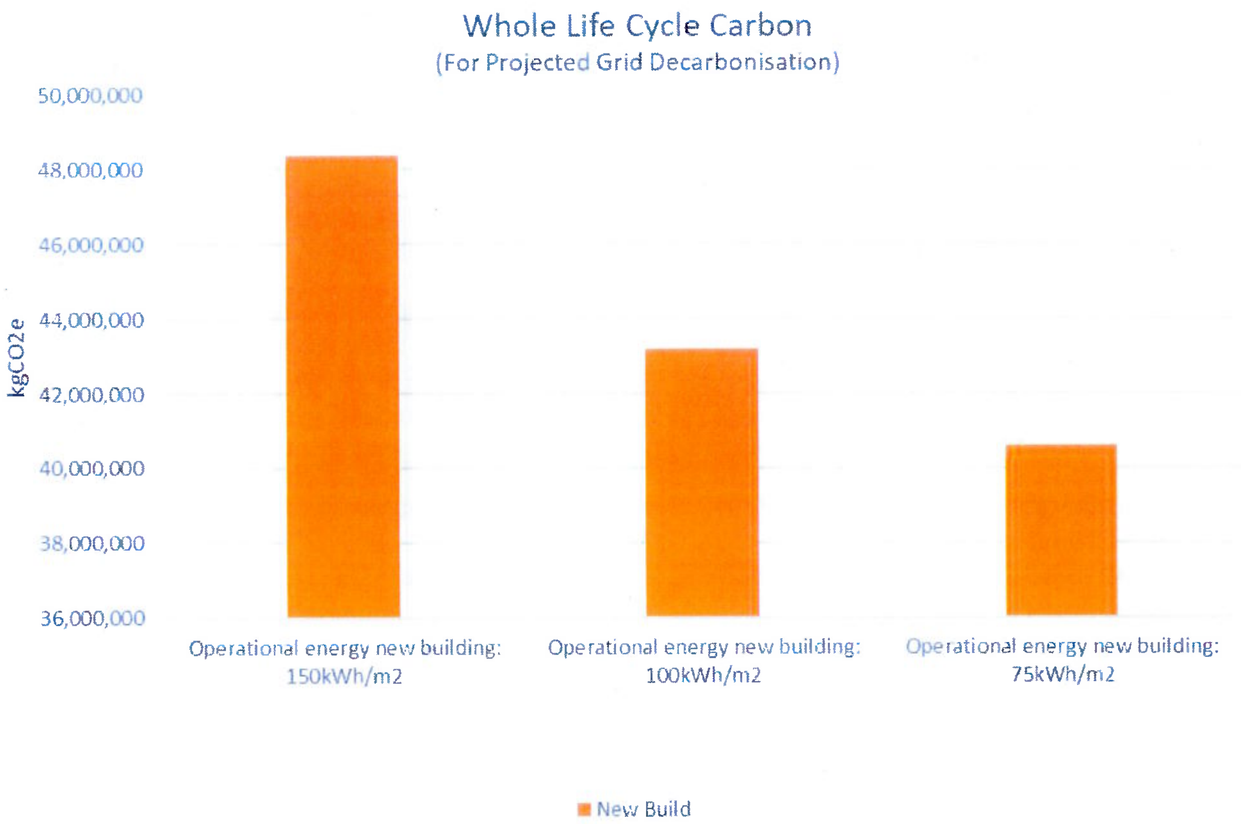


*Figure 1: Whole Life Cycle Carbon Emissions*

# Contents

# 1 Background

The building and construction sector are a major contributor to global greenhouse gas emissions. The 2022 Global Status Report for Buildings and Construction reported that the sector accounted for over 34% of energy demand and around 37% of energy and process-related $CO_2$ emissions in 2021.

To date the construction industry has primarily focused on operational carbon emissions, i.e. emissions from energy consumption in the day-to-day running of a property, via targets in building regulations (Part L) and voluntary sustainability assessment rating schemes (LEED, BREEAM, etc.). Until recently, embodied carbon emissions - emissions associated with raw material extraction, transportation, manufacturing, construction, maintenance, renovation, and end-of-life (e.g. disposal), have largely been ignored. However, as carbon emissions within the built environment have become better understood, the industry has started to transition to Whole Life Carbon (WLC) Assessments.

As the name suggests, Whole Life Carbon (WLC) Assessments consider the whole life cycle of the building, including manufacturing, transport, use and final disposal of the resources required for the delivery of the building functions for the whole period which the assessment covers. The various stages of a typical building life cycle are defined in the life-cycle methodology set in the European Standard EN 15978. These are:

- A: the production and construction stages,
- B: the use stage,
- C: the end-of-life stage, and
- D: externalized impacts beyond the system boundary.

Each stage includes multiple modules, as shown in Figure 2. Whole life carbon can be broken down into two main categories:

1. Embodied Carbon, and
2. Operational Carbon.

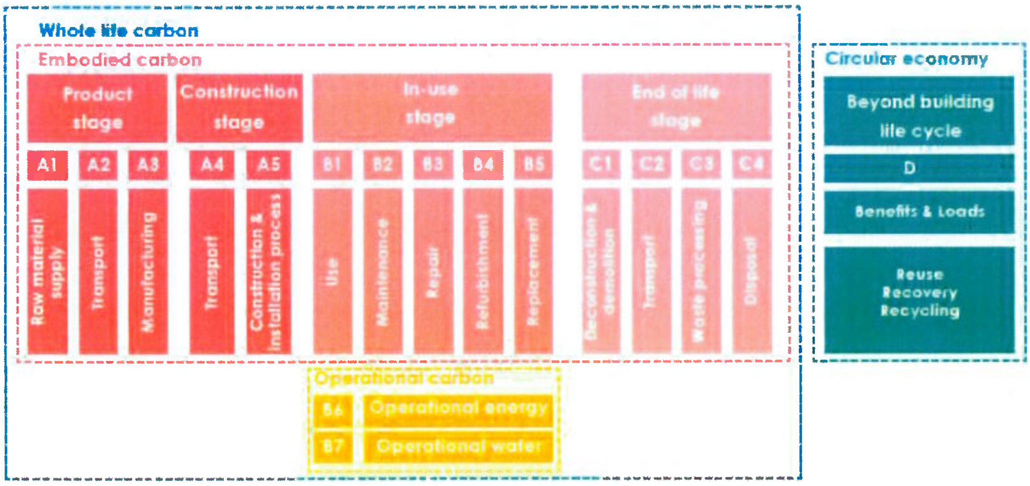


*Figure 2: Whole Life Carbon Stages (Image Courtesy (LETI, 2020))*

Embodied carbon is the carbon dioxide ($CO_2$) or greenhouse gas (GHG) emissions associated with materials and construction processes throughout the whole life cycle of an asset (modules A1-A5, B1-B5, C1-C4). Embodied carbon is typically measured in $kgCO_2e$ and often reported per square meter (gross area) as $kgCO_2e/m^2$.

Operational carbon should be based on real energy consumption data, if available. For design stage calculations, predictive modelling or benchmark figures relevant to the building type and location must be used. Although an early-stage energy model has been created for the proposed building, this model relies heavily on assumptions and at this stage of the design it is not a reliable prediction of actual operational energy due to unknowns on the potential occupier of the building, their requirements and their usage of the building. Therefore, the approach of analysing different benchmark operational energy figures, rather than a discrete operational energy data point from the energy model, provides a better understanding of the impact of operational energy on whole life carbon emissions and carbon payback.

The Royal Institute of the Architects of Ireland (RIAI) 2030 Climate Challenge report provides current benchmarks and 2025 and 2030 targets for embodied carbon and operational energy in new-build offices in Ireland as per Figure 3.

| Sustainable Outcome metrics | Current Benchmarks | 2025 Targets | 2030 targets | Notes Non-Domestic |
|---|---|---|---|---|
| Operational Energy - kWh/m2/y | < 150kWh/$m^2$ | 75kWh/$m^2$ | **55kWh/$m^2$** | Targets are based on Gross Internal Area (GIA). Figures include both regulated & unregulated energy consumption; irrespective of the source of that energy (e.g. whether it is from the (grid or generated by renewables). This differs from the Non-domestic Energy Assessment Procedure (NEAP), which calculates the energy demand for space and water heating, ventilation and lighting and the electrical energy delivered to the building for these demands. DEAP then calculates the CO2 emissions and primary energy associated with this electrical energy.<br><br>Current benchmarks based on Part L 2017 estimates for typical compliant buildings.<br><br>In order to meet targets:<br>1. Use a 'Fabric First' approach<br>2. Minimise energy demand. Use efficient services and low carbon technologies<br>3. Maximise onsite renewables |
| Embodied Carbon kgCO2e/$m^2$ | < 1400 kgCO2e/$m^2$ | < 970 kgCO2e/$m^2$ | < 750 kgCO e/$m^2$<br><br>(A1-A5 < 475 kgCO e/$m^2$) | To assess embodied carbon, use EN 15978 and Level(s) GWP Indicator (modules A1-A5 B1-B5, C1-C4 including sequestration). Analysis should include minimum of 95% of cost, include substructure, superstructure, finishes, fixed FF&E building services and associated refrigerant leakage.<br>Current benchmarks aligned with LETI band E; 2025 target aligned with LETI band C and 2030 target aligned with LETI band B.<br><br>In order to meet targets:<br>1. Perform Whole Life Carbon Analysis<br>2. Use circular economy strategies<br>3. Minimise offsetting, use Irish schemes (CCC) |

*Figure 3 RIAI 2030 Climate Challenge embodied carbon and operational energy targets for office buildings [Image credit: (RIAI, 2021)]*

While the RIAI 2030 Climate Challenge embodied energy targets should be achievable for most new build office buildings, the targets set for operational carbon are very ambitious. Considering plug-loads (unregulated operational energy, e.g. monitors, computers, tea/coffee making equipment) typically make up about 30% of an office building's energy use, the energy use for all other "regulated" equipment, e.g. HVAC, etc., would need to be unrealistically low, particularly for the 2030 55kWh/$m^2$ target. It is likely that operational energy will have to be considerably higher than the RIAI 2030 Climate Challenge targets to meet the needs of modern offices, but operational carbon can be reduced by electrifying buildings, relying on the electricity grid becoming cleaner or achieving net zero carbon for the operation of the building by entering into a Corporate Power Purchase Agreement (CPPA). This is not to say that measures to reduce energy consumption are not important, they should be the first step in reducing operational carbon emissions, but based on current actual operational energy for some of the most efficient office buildings in Ireland and the UK today, and the requirements of modern office environments, 55kWh/m$^2$ is likely to remain outside what is realistically feasible even by 2030. To provide some frame of reference for the RIAI operational energy targets, Table 3 provides operational energy benchmarks from a number of CIBSE sources (granted these are now over 10 years old).

*Table 3: CIBSE Operational Energy Benchmarks*

| Data Source | Benchmark/Target (kWh/m2.yr) | | |
|---|---|---|---|
| | Electricity | Fossil Fuel | Total |
| CIBSE TM46: 2008<br>General Office | 95 | 120 | 215 |
| CIBSE Guide F 2012<br>Offices Air-Conditioned, standard; Typical Practice | 226 | 178 | 404 |
| CIBSE Guide F 2012<br>Offices Air-Conditioned, standard; Good Practice | 128 | 97 | 225 |
| RIBA 2030 Climate Challenge 2025 Target | | | <75 |
| RIBA 2030 Climate Challenge 2030 Target | | | <55 |

# 2 Introduction

BPC Engineers were contracted to perform a Whole Life-Cycle Carbon (WLC) Assessment for the demolition of the existing disused former City Arts Centre Building and construction of a 24 storey mixed use building containing an arts centre, office and café accommodation, and exhibition performance space on a parcel of land which includes 1-4 City Quay, Dublin 2 D02KT32, 23-25 Moss Street, Dublin 2 and 5 City Quay, Dublin 2. The analysis in this report assesses the whole life-cycle carbon for the proposed development.

The existing building is a three storey property, constructed in the 1850's, whit a Gross Internal Area (GIA) of 1,404 $m^2$. It is characterised by a loadbearing brick masonry construction with timber joist floors. This building was previously home to the City Arts Centre which was a significant cultural building in Dublin City but it has been in disuse for a significant number of years and has become severely derelict and unsafe for pedestrians passing by along Moss Street or City Quay. It is therefore considered appropriate to demolish the existing building in order to provide a cultural space that is fit for purpose and can become a significant part of the Dublin City community again. The south of the site is made up of hardstanding areas which is used as a car park.

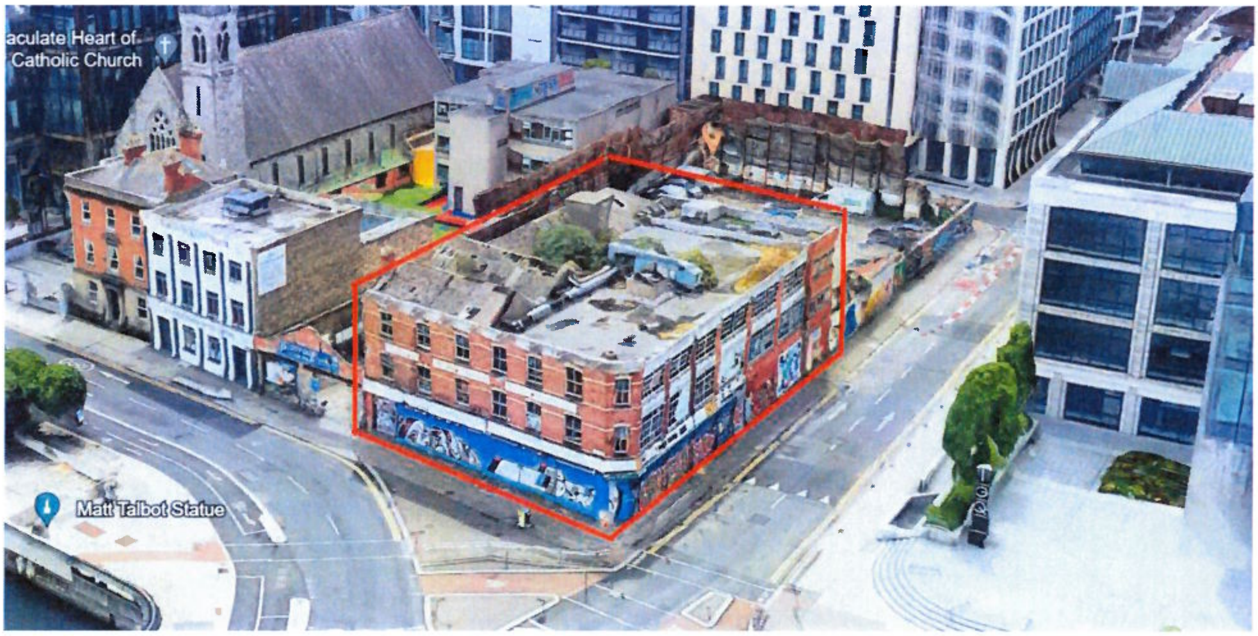


*Figure 4 former City Arts Centre Building (Courtesy Google Maps)*

The proposed development will deliver a 24 storey, 108m tall, mixed-use building containing an arts centre, office and café with 2 basement levels providing cyclist facilities, car parking, plantrooms and exhibition-performance space. The approximate floor areas are 32,030$m^2$ above ground and 3,880$m^2$ below ground, totalling 35,910$m^2$. The approximate floor areas of the Arts Centre, Office and Gym are 1404$m^2$, 22,587$m^2$ and 244$m^2$ respectively. The massing of the building steps as the building rises from a six-storey shoulder height fronting the quays to the twenty-four storey tower. A series of stepped back terraces at 7th, 9th and 11th floors transition the form of the building from the base of the tower. The lower floors form a base to the tower and are located in a black brick frame with glazing infill. The frame presents two-storey high columns at 3000mm centres. In contrast, the tower is wrapped in curtain walling with 750mm wide vertical aluminium bands also at 3000mm centres. These bands contain patterned louvres which allow air transfer to the on-floor mechanical ventilation system as well as the demand control ventilation system.

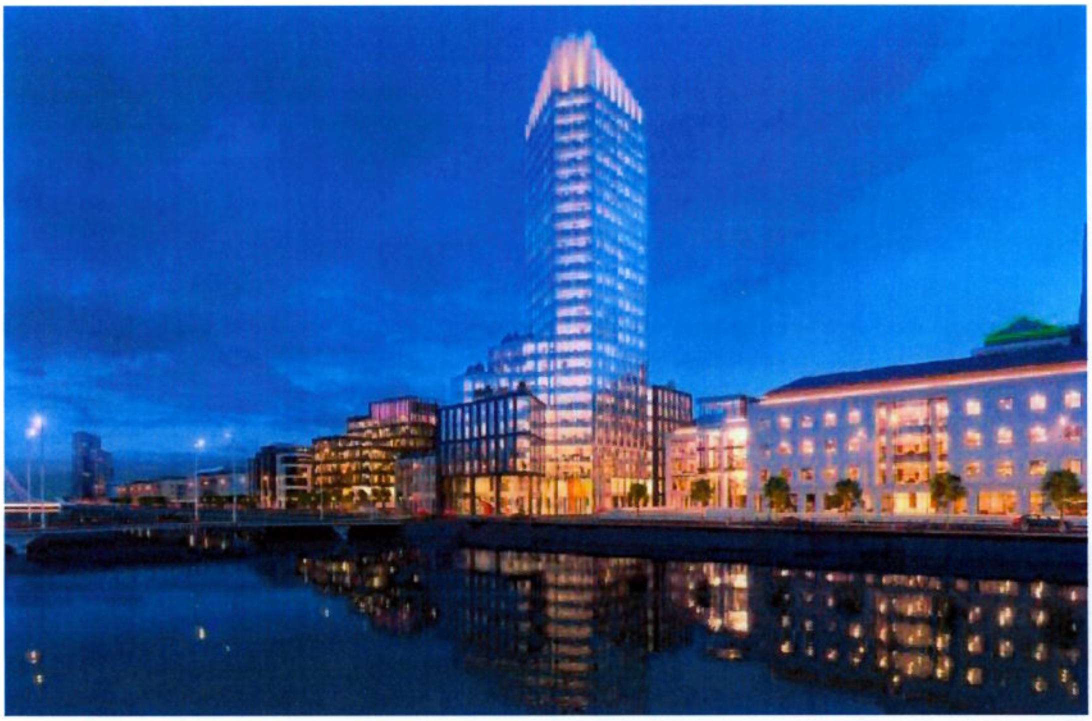

*Figure 5 CGI of proposed development (Source: Digital Dimensions)*

The embodied carbon emissions are calculated in line with EN 15978 for the carbon life-cycle stages A1-A5, B1-B5 and C1-C4 using Life-Cycle Analysis (LCA) software. As the project is only at planning stage, no full bill of quantities has been developed yet. Therefore, the analysis relied on bills of quantities available along with data from several similar office projects that are in the construction phase. The projects are similar with respect to their proposed designs, including materials. They all have concrete sub-structures with steel frame superstructures. To account for the fact that the projects are not all the same size, the quantities of materials were appropriately scaled based on the relative areas. The embodied carbon calculation can be updated once a detailed bill of quantities is available for this project.

The impact of different operational energy consumption on "carbon payback" are assessed. The operational energy figures used for the proposed new development (kWh/m$^2$.yr) are based on current best practice operational energy figures and target operational energy figures suggested by the Royal Institute of the Architects of Ireland (RIAI) as part of the RIAI 2030 Climate Challenge.

This report provides the results of the whole life carbon (WLC) assessment, including:

- The total embodied carbon for the new build,
- A breakdown of the embodied carbon by building element classification, e.g. foundations, facade, etc.,
- Identification of potential areas for embodied carbon reduction, and
- a whole life-cycle carbon emission assessment including operational carbon.

# 3 Methodology

## 3.1 General Inputs & Assumptions

- Floor area (GIA) of approximately 35,910m$^2$ for the New-Build.
- The life-span/calculation period for the building is 60 years.

## 3.2 Embodied Carbon

The embodied carbon emissions are calculated in line with EN 15978 for the carbon life-cycle stages A1-A5, B1-B5 and C1-C4 using Life-Cycle Analysis (LCA) software. The software is aligned with the calculation requirements for EN 15978 and provides a comprehensive Environmental Product Declaration (EPD) database to choose from. Refer to Appendix A for further details on OneClick LCA software.

### 3.2.1 Data Sources

The analysis has been performed using the data sources outlined in Table 4.

*Table 4: Data Sources*

| Data type | Data source |
|---|---|
| Material quantities (A1-A3) | Pro rata bills of quantities from similar office projects which are in construction phase. |
| Material transport distances (A4) | Regionally applicable transportation scenarios from One Click LCA. Those represent regionally typical transportation distances and methods for product types, which are relevant when no decisions on suppliers are made. |
| Construction and installation (A5) | Impacts are based on conservative default values from One Click LCA. |
| Material impacts in use (B4-B5) | Material service life is based on the typical values for the materials in question, which have been reviewed for relevance to this project. The values have been adjusted where necessary. Material maintenance and repair activities have not been included in scope. Materials have been assumed to be replaced in their entirety at the end of their service life. |
| End of life impacts (C1-C4) | End of life impacts are based on One Click LCA's scenarios which represent the typical end of life processing for material types in compliance with the requirements of the EN 15804+A1. |

### 3.2.2 Calculation Inputs

This section describes the key assumptions made for each module as part of the embodied carbon modelling process. Not every single assumption is listed, but the key items that influenced the process are presented below.

Table 5 outlines the building parts, elements and components included in the embodied carbon calculation for EN 15978.

*Table 5: Building Elements Included in this analysis as per ILFI*

X = optional inclusions for ILFI certification, but have been included for this analysis.

X = optional inclusions for ILFI, which have been excluded from this analysis.

| Element Category | Building Element | ILFI |
|---|---|---|
| **1 Substructure** | Foundations, pads and piles | x |
| | Rising walls | x |
| | Ground floor construction | x |
| **2 Superstructure** | Frame – Beams, Columns & Walls | x |
| | Upper floors incl. balconies | x |
| | Roof | x |
| | Stairs and Ramps | x |
| **2.1 Enclosure** | Cladding and Insulation | x |
| | Windows / Curtain Wall | x |
| | External Doors | x |
| | Roof covering and insulation | x |
| **2.2 Internal walls** | Partitions and insulation | x |
| | Internal Doors | x |
| **03 Finishes** | Wall finishes | x |
| | Floor finishes | x |
| | Ceiling finishes | x |
| | Furniture & Sanitaryware | x |
| **04 Building Services** | Heat Recovery Ventilation Units (OneClick GIFA) | x |
| | VRF indoor and outdoor units | x |
| | Hot & Cold Water Supply | x |
| | In-built lighting | x |
| | Elevators | x |
| **05 External Works** | Road, paths, paving and surfacing | x |
| | External drainage | x |

## Modules A1 – A3

Main building material specifications used in the analysis are reported in Table 6. Where available, manufacturer EPD's have been selected which match the reference BOQs. Where an exact match manufacturer EPD is not available, the closest match within the OneClick LCA dataset has been selected which complies with EN 15978. Data sources within the One Click LCA database are approved EPD's which have been verified by a third party. These can be further refined when more detailed information becomes available.

*Table 6: Specifications for building materials*

| Building element | Modelling assumptions |
|---|---|
| Foundation, sub-surface, basement | Ready-mix concrete - C32/40<br>30% Ground Granulated Blast-furnace Slag |
| Horizontal structures: beams, floors and roofs | Ready-mix concrete - C32/40<br>30% Ground Granulated Blast-furnace Slag |
| Vertical structures and facade | Ready-mix concrete - C32/40<br>30% Ground Granulated Blast-furnace Slag |
| Reinforcement steel (rebar) | Generic steel - 90% Recycled content |
| Structural steel | Cold formed steel - 20% Recycled content |
| Curtain wall | Aluminium framed curtain wall, glazing 76-100% |
| Brick bay | Clay brick + Mortar |
| Underground wall | Concrete block underground retaining wall assembly |
| Roof plant screen | Aluminium rainscreen cladding for façade |
| Partition walls – Office area | Gypsum plasterboard with glass wool insulation |
| Ceiling – Office area | Suspended ceiling system |
| Floor – Office area | Raised access flooring system, 60 - 380 mm Variable height, |
| Roof | Terrazzo slabs and tiles, 1-1/4 inch,<br>Bitumen sheets for waterproofing |
| Internal walls | Wall paints for interior use |

**Module A4**

Default transport distances have been selected from the OneClick LCA database. These can be further refined when more detailed information becomes available. However, the transport distance selected will likely have a negligible impact on the results due to the small contribution of embodied carbon (GWP) associated with transport. The initial assumptions are set out below.

*Table 7 Transport distances for key materials in the model*

| Product | Assumed transport distance (km) |
|---|---|
| Concrete, Plasterboard, Tiles and asphalt | 60 |
| Steel, Paints, Aluminium, Insulation, Raised access floor, Bitumen, Doors, Building systems | 100 |
| Elevators | 700 |

**Module A5**

Module A5 covers all on or off-site construction activities, including any energy consumption for the site accommodation, plant use and the impacts associated with any waste generated through the construction process, including treatment and disposal. Default values have been selected from the OneClick LCA database.

**Module B4 - B5**

The replacement emissions associated with key materials over the development's modelled 60-year life cycle are included in Modules B4 and B5. The actual procurement details for most products and materials are unknown, therefore default service life values have been selected from the OneClick LCA database. These values are reported in Table 8, but they should be reviewed and refined once manufacturer data becomes available.

Materials that have a design life that match that of the overall building, including the majority of substructure and superstructure elements, are not included in the table.

*Table 8: Service Life of High Impact Products*

| Building parts | Material specification | Service life (years) |
|---|---|---|
| Partition walls – Office area | Gypsum plasterboard with glass wool insulation | 30 |
| Ceiling – Office area | Suspended ceiling system | 25 |
| Floor – Office area | Raised access flooring system, 60 - 380 mm Variable height, | 25 |
| Internal walls | Wall paints for interior use | 10 |
| Building systems | HVAC system | 20 |

**Module C1 – C4**

The end of life processes used in the analysis are in line with the standard scenarios assigned by One Click LCA for the building materials. These are reported in Table 9.

*Table 9: Specifications for building materials*

| Building parts | Material specification |
|---|---|
| Foundation, sub-surface, basement | Concrete crushed to aggregate (for sub-base layers) |
| Horizontal structures: beams, floors and roofs | Concrete crushed to aggregate (for sub-base layers) |
| Vertical structures and facade | Concrete crushed to aggregate (for sub-base layers) |
| Reinforcement steel (rebar) | Steel recycling |
| Structural steel | Steel recycling |
| Curtain wall | Glass recycling |
| Brick bay | Brick/stone crushed to aggregate + Cement/mortar use in backfill |
| Underground wall | Concrete crushed to aggregate (for sub-base layers) |
| Roof plant screen | Aluminium recycling |
| Partition walls – Office area | Steel and Gypsum recycling |
| Ceiling – Office area | Steel recycling |
| Floor – Office area | Steel recycling |
| Roof | Brick/stone crushed to aggregate<br>Landfilling (for inert materials) |
| Internal walls | Landfilling (for inert materials) |

### 3.2.3 Exclusions from the Analysis

Phases B1 (In-use phase), B2 (maintenance) and B3 (repair) are not considered core modules which contribute to embodied carbon and therefore have not been included in this analysis. Once operation and maintenance manuals become available for the project, analysis of these phases can be added but they will not have any major impact on results. These phases are also typically excluded from the LETI/RIAI and ILFI standards.

## 3.3 Whole Life Carbon (WLC)

The WLC assessment considers embodied carbon (building LCA stages A1-A5, B4-B5 and C1-C4) and operational carbon over a 60 year period. As described in section 3.1, Life-Cycle Analysis (LCA) software was used to calculate embodied carbon in line with EN 15978 for the carbon life-cycle stages A1-A5, B1-B5 and C1-C4. The operational carbon for the new building was calculated based on three different annual operational energy figures: 150 $kWh/m^2$, 100 $kWh/m^2$ and 75 $kWh/m^2$. Additionally, the operational energy/carbon calculations considered two different grid decarbonisation scenarios:

1. **Estimated grid decarbonisation**: Projected electricity grid decarbonisation based on historical average decarbonisation rate.
2. **Slower decarbonisation:** Decarbonisation of the grid slower than projected in option 1 (approximately 50% slower over a 60 year period.)

### 3.3.1 Calculation Inputs

**Fuel**

Electricity only for new build.

**Carbon emission factor**

Projected Grid Decarbonisation (Scenario 1):

It is recommended to use an annual lifetime carbon emission factors. At present this is 0.07 $kgCO_2/kWh$ for the average content of the UK grid over the next 30 years. There are currently no available figures on the Ireland grid. The Ireland grid is different from the UK. For example, it does not use domestically generated nuclear power. However, in the absence of data on the Ireland grid for long term carbon emissions, the same average emissions factor has been used as an estimate. This annual lifetime carbon emission factor represents a relatively rapid decarbonisation of the grid over the next 30 years which is line with Ireland's emissions targets. Based on Ireland's current emission factor for electricity (0.224 $kgCO_2/kWh$), a 30 year average of 0.07 $kgCO_2/kWh$ would require a 10% year-on-year reduction approximately for the next 30 years. (The carbon emission factor is per kWh primary energy. Delivered energy should be first multiplied by the primary energy factor). The reduction was extrapolated for up to 60 years. (The grid is essentially assumed to converge to zero carbon emissions over this period.)

Grid Decarbonisation 50% Slower (Scenario 2):

An additional set of scenarios are also analysed where the grid decarbonises at a slower rate. This is included to show the impact that decarbonising the grid has on carbon payback. For these scenarios it is assumed that it takes 60 years (versus 30 years) for the grid to reach an average carbon emission factor of 0.07 $kgCO_2/kWh$. (This does not indicate that at year 60 the emission factor is 0.07 $kgCO_2/kWh$, rather that the average over the 60 year period is 0.07 $kgCO_2/kWh$.)

**Primary Energy**

Projected Grid Decarbonisation (Scenario 1):

The current primary energy factor for electricity is 1.75. This has reduced by an average of approximately 3% year-on-year since 2001. The same reduction is assumed for the upcoming years up to a minimum primary energy factor of 1.1. This equates to a year-on year reduction of approximately 3% for 15 years before it is assumed to remain constant at 1.1. The minimum primary energy factor of 1.1 is just an assumption. It may be higher/lower depending on multiple factors. There will always be some losses associated with transmission and distribution and other parasitic loads such as pumped storage. Again, an additional scenario where the grid decarbonises at a slower rate (resulting in higher primary energy factors due to less efficient generation) is also included to show the impact that decarbonising the grid has on carbon payback.

Grid Decarbonisation 50% Slower (Scenario 2):

The primary energy factor and carbon emission factor are intrinsically linked. As more renewables are added to the grid and the carbon emission factor is reduced, the primary energy factor also reduces because the generation efficiency for sources such as wind is close to 100% (compared to only around 50% for combined cycle gas turbines CCGT). However, there is also a decoupling of these factors as the need for more storage mechanisms, e.g. pumped storage etc. is increased, thus adding additional parasitic loads to the grid. Attempting to accurately predict the primary energy factors and carbon emission factors is beyond the scope of this analysis. For the purpose of the second scenario analysis (slower decarbonation of grid) it is assumed that the primary energy factor reduction slows to an average of 2% per year (versus 3%) until it reaches a minimum of 1.1.

**Upfront Embodied Carbon (LCA stages A1-A5)**

The upfront embodied carbon (LCA stages A1 – A5) is calculated using LCA software as described in section 3.2. The embodied carbon emissions for these stages is added at year 0. The "In-Use" (B1-B5) emissions are added in two equal measures at 20 years and 40 years. In reality, there are some yearly emissions associated with stages B1-B3 but the above is an approximation based on major equipment replacement and refurbishments being completed at 20 year intervals. The LCA end-of-life stages (C1-C4) embodied carbon are assumed to be the same and do not impact the carbon payback calculations. See Table 11 for further details.

**Operational Carbon**

The operational carbon for the new building was calculated based on three different annual operational energy figures: 150kWh/m$^2$, 100kWh/m$^2$ and 75kWh/m$^2$, as previously described. These figures are based on the RIAI 2030 Climate Challenge benchmarks and target metrics for office buildings. However, the 2030 55kWh/m$^2$ target operational figure has been omitted as it is expected that this level of operational energy is likely remain below what is realistically feasible in large-scale office buildings, even by 2030. (See Section 1 'Background' for further information.)

# 4 Results

## 4.1 Embodied Carbon

Table 10 shows the total embodied carbon emissions in Tons $CO_2e$ and $kgCO_2e/m^2/yr$. This excludes carbon emissions associated with the B6 operational carbon, as it will be analysed in the following section of this report. Table 11 provides a breakdown of the carbon emissions for each of the LCA stages included in the embodied carbon analysis.

*Table 10 Embodied Carbon LCA analysis results*

| Building | Total embodied carbon emission ($TonsCO_2e$) | Total embodied carbon emission ($kgCO_2e/m2$) |
|---|---|---|
| City Quay - New building | 25,332 | 705 |

*Table 11: Embodied Carbon breakdown by LCA Stages*

| EN15978 LCA Stages | | Carbon Emissions ($KgCO_2e$) | Intensity (kgCO2e/m2) | Breakdown % |
|---|---|---|---|---|
| City Quay – New building | | | | |
| A1-A5 | A1-A3 Materials | 15,339,684 | 427 | 61% |
| | A4 Transport | 363,175 | 10 | 1% |
| | A5 Construction | 1,088,121 | 30 | 4% |
| | Total | 16,790,980 | 468 | 66% |
| B4-B5 Replacement | | 8,009,096 | 223 | 32% |
| C1-C4 End of Life | | 531,700 | 15 | 2% |
| Total | | 25,331,776 | 705 | 100% |

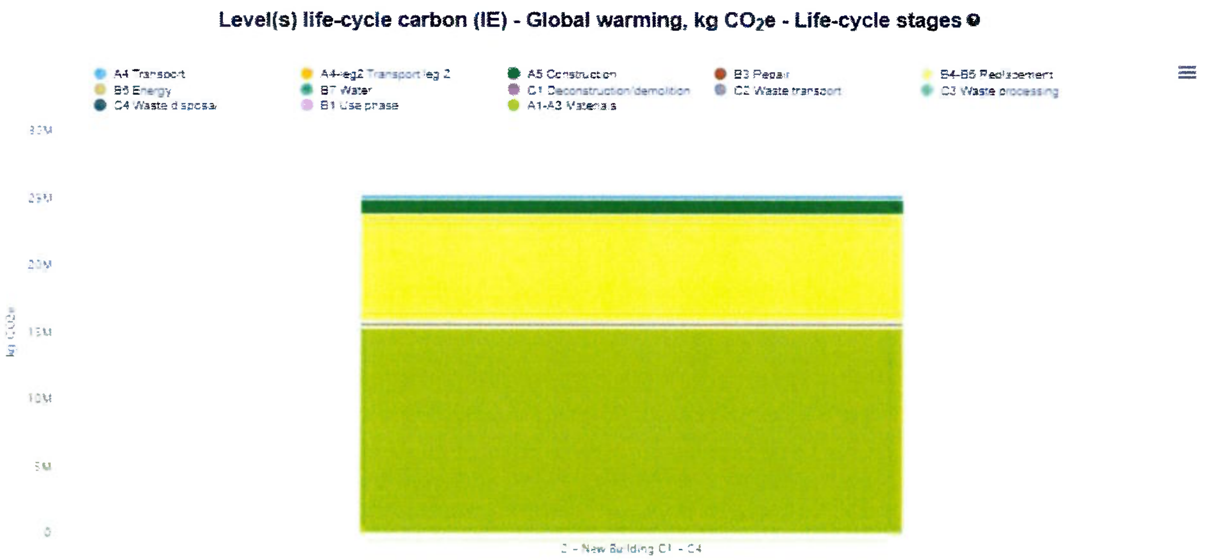


*Figure 6: Embodied Carbon - Life-cycle Stages*

Life-cycle stages A1-A3 (Materials/Product Stage) represent 61% of the total life-cycle embodied carbon for the new building. This highlights the importance of selecting low embodied carbon material where possible.

*Table 12: New Build Main Contributors to Cradle to Gate Embodied Carbon by Resource*

| Resource | Cradle to Gate (A1-A3) % |
|---|---|
| Ready-mix concrete (30% GGBS) | 23.0% |
| Reinforcement steel (rebar) (90% recycled content) | 13.7% |
| Structural steel profiles (20% recycled content) | 9.1% |
| Aluminium framed curtain wall, glazing 76-100% | 15.0% |
| Raised access flooring system | 9.1% |

Life-cycle stages B4-B5 (repair and replacement) are the next biggest contributors (by LCA stage) and are an important consideration when determining which elements to target first with respect to reducing embodied carbon (EC). For example, the up-front EC (stages A1-A3) associated with rebar is about 13.7% of the total EC (for these stages) and the raised access flooring accounts for about 9.1% of EC for the same stages. However, when the whole life-cycle (stages A-C), including replacement is considered, the raised access floor constitutes 17.2% of the overall EC while the rebar falls to 9.3%. Therefore, when assessing which building elements to target first, it is important to consider the whole building lifecycle.

*Table 13: New Build Main Contributors to Whole Life Embodied Carbon by Resource*

| Resource | Embodied Carbon % (A-C) |
|---|---|
| Ready-mix concrete for external walls and floors | 16.5% |
| Raised flooring systems | 17.2% |
| Structural steel and steel profiles | 17.4% |
| HVAC components and equipment | 11.4% |
| Glass Façade incl. frames | 9.2% |

Figure 7 shows the embodied carbon of the various building elements for the new building.

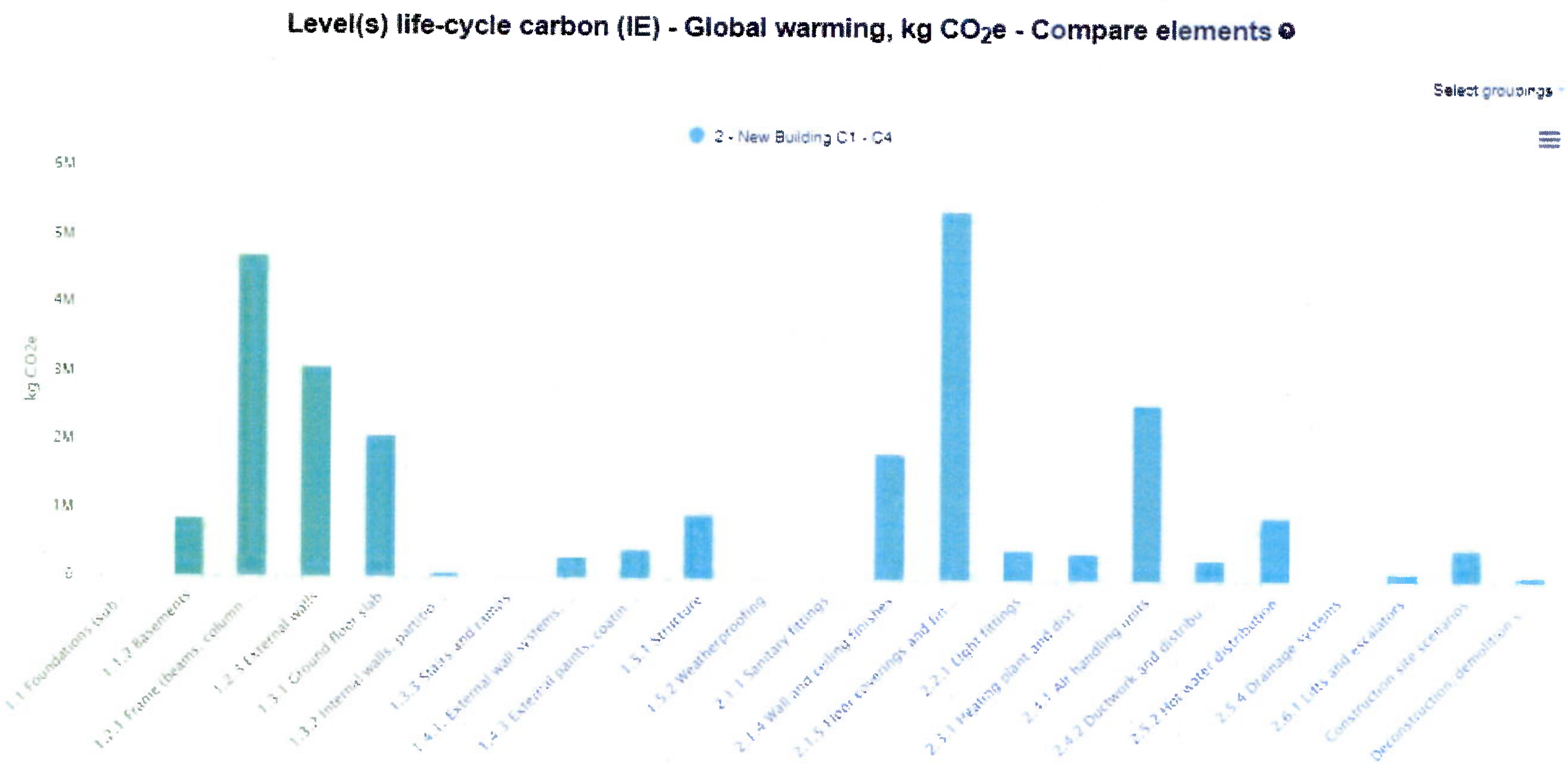


*Figure 7 Embodied Carbon Comparison – Building Element Classifications*

### 4.1.1 Embodied Carbon Reduction Options

To reduce embodied carbon the elements/resources with the highest life-cycle embodied carbon (EC) should be considered first.

#### *4.1.1.1 Concrete*

Ready-mix concrete for external walls and floors constitutes about 16.5% of the total EC. Replacing a percentage of the Portland cement (Pc) with low carbon alternatives can significantly reduce the EC of concrete. Pulverised Fuel Ash (PFA), commonly know as 'Fly ash' is one cement substitute. It is employed in ratios ranging from 80% Pc and 20% PFA – 60% Pc and 40% PFA, according to the ultimate function of the cement. Ground Granulated Blast-furnace Slag (GGBS) is another cement substitute. As with PFA, it is always used in combination with Portland cement, typically in the range 60% Pc and 40% GGBS - 30% Pc and 70% GGBS. The current design assumes 30% GGBS in all concrete ready-mix products. The availability of GGBS and/or fly ash and it's impact on the project programme should be investigated by the design team to determine how much GGBS/fly ash is feasible to include in the concrete mix. Careful management of the construction programme may provide opportunities to increase the GGBS content in concrete.

#### *4.1.1.2 Structural Steel*

Structural steel and steel profiles account for about 17.4% of EC. Due to the high EC of steel, the amount of steel required should be reduced where possible. Where steel is required the recycled content should be maximised. The analysis currently assumes 20% recycled content in structural steel and 90% recycled content in steel reinforcement (rebar).

#### *4.1.1.3 Aluminium in Facade*

The embodied carbon of a façade will vary significantly depending on the system type and design. The current design has aluminium framed curtain wall. The aluminium is a significant contributor to the embodied carbon of the facade. The current analysis assumes a global warming potential for the aluminium used of 9 $kgCO_2/kg$. Recycled aluminium consumes roughly 10% of the energy of virgin sourced material so choosing products that use recycled aluminium can reduce EC significantly. By increasing the recycled content of aluminium and using renewable energy supplies in its production, the embodied carbon associated with the aluminium can be dramatically reduced. Lower carbon products are available compared to what is currently assumed. For example, the company Hyrdo produces a series of low carbon aluminium products in their Hydro REDUXA range. The aluminium in these products has a maximum carbon footprint of 4.0 $kgCO_2/kg$.

#### *4.1.1.4 Raised Flooring Systems*

The raised flooring systems account for approximately 17.2% of EC. Low carbon alternatives to traditional systems should be investigated. Calcium sulphate raised floor systems are becoming more popular as an alternative option and come with a service life of 50 years instead of 20-25. By selecting a calcium sulphate raised floor system instead of a traditional system a reduction up to 8% of the embodied carbon of the building is expected. One of the prominent players in the calcium sulphate board raised access floor market is Kingspan. Kingspan has a new panel (RMG600+) produced using a minimum of 86% recycled content and low carbon steel and it is characterised by a 57% reduction (A1-C) per panel, compared to previous raised floor panels in their range.

#### *4.1.1.5 HVAC Equipment*

HVAC components and equipment constitute 11.4% of the total EC. In order to reduce the EC associated with HVAC equipment the design team should look at:

- Reducing amount of equipment/material.
  - Consider number of pieces of equipment required. Can this be reduced?
  - Reduce the length/size of pipe runs and ventilation ductwork where possible.
- Consider equipment EC when specifying equipment and selecting lower EC options where possible.

    - Particular attention to be paid to AHUs where units may be custom and may offer more flexibility with regard to specifications compared to other equipment.
- Whole lifecycle needs to be considered including operational energy as there is no point in reducing embodied carbon if the impact on operational carbon negates the reduction.

### 4.1.2 Comparison to existing benchmarks

The section provides comparisons to existing benchmarks to evaluate the building's performance. Although, LCA benchmarks for embodied carbon are still not well established in the construction industry, there are some organisations providing benchmarks and targets. These include:

- The International Living Future Institute (ILFI)
  - Targets provided within their Zero Carbon Certification scheme.
- The Low Energy Transformation Initiative (LETI)
  - Benchmarks and targets provided in serval publications
  - Multiple case studies
- Carbon Heroes Benchmarking
  - Benchmarking tool created by OneClick LCA
  - Provides embodied carbon benchmarks for different building types across different countries.
  - The data is compiled from thousands of anonymised, verified building projects using One Click LCA software.
- Royal Institute of Architects of Ireland (RIAI) 2030 Climate Challenge
  - Sets current benchmark and targets for 2025 and 2030

#### *4.1.2.1 International Living Future Institute (ILFI) Net Zero Carbon*

ILFI Zero Carbon Certification is still in its infancy but it is beginning to gain traction in Ireland with owners of commercial, warehouse and industrial building types who wish to gain Zero Carbon Certification. As a prerequisite, projects must achieve less than 500 kgCO2e/m2 for embodied carbon stages A1-A5. It is worth noting that the benchmark figure from the ILFI of 500 $kgCO_2e/m^2$ does not include M&E systems, while the analysis carried out for City Quay does include the embodied carbon associated with the M&E systems.

#### *4.1.2.2 LETI*

According to LETI, for buildings that are currently in the design stage: a good design should achieve a LETI band C, meaning that the embodied carbon stages A1-A5 should be between 600 and 475 $kgCO_2e/m2$.

**Upfront Embodied Carbon, A1-5** (exc. sequestration)

| | Band | Office | Residential (6+ storeys) | Education | Retail |
|---|---|---|---|---|---|
| | A++ | <100 | <100 | <100 | <100 |
| | A+ | <225 | <200 | <200 | <200 |
| LETI 2030 Design Target | A | <350 | <300 | <300 | <300 |
| | B | <475 | <400 | <400 | <425 |
| LETI 2020 Design Target | C | <600 | <500 | <500 | <550 |
| | D | <775 | <675 | <625 | <700 |
| | E | <950 | <850 | <750 | <850 |
| | F | <1100 | <1000 | <875 | <1000 |
| | G | <1300 | <1200 | <1100 | <1200 |

*Figure 8 LETI Upfront Embodied Carbon bands*

#### *4.1.2.3 Carbon Heroes Benchmark Program*

The carbon hero benchmark program is the only benchmark which includes life-cycle stages A1-A3, A4, B4-B5, and C1-C4. The collection of building information for the development of this benchmark is the result of material quantity inputs made by users of One Click LCA.

The comparison of the results with the values collected by the carbon hero benchmark program is implemented by the One Click LCA software though a performance metric developed using the sample selected by the user. The performance metric associated with the sample "Western Europe office" is shown in Figure 9. The sample includes 249 buildings predominantly from UK (62%).

Figure 9 shows that the embodied carbon result obtained for the new building falls within band "D", thus is in line with the average embodied carbon of the buildings of the sample considered.

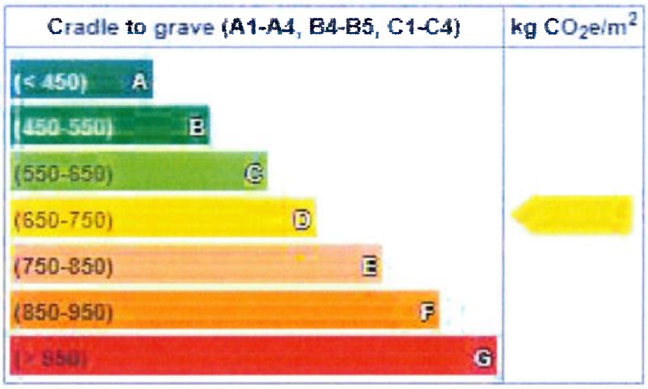


*Figure 9 Performance metric Carbon Heroes Benchmark – New building*

#### *4.1.2.4 Embodied Carbon Benchmark Study*

The Embodied Carbon Benchmark Study, published by the Carbon Leadership Forum in February 2017, surveyed the carbon footprints of over 1000 LCA studies of buildings. One major finding of this study was that the typical upfront embodied carbon (life cycle stages A1-A5) of a building's structure, foundation, and enclosure is typically less than 1000 $kgCO_2e/m^2$. The upfront embodied carbon for commercial office buildings was between 200 and 500 $kgCO_2e/m^2$ for 50% of buildings in the database considered in the study.

Table 14 shows that the upfront embodied carbon calculated for the new building is in line with the benchmarks presented.

*Table 14 Upfront embodied carbon result and benchmarks*

| | | Upfront embodied carbon ($kgCO_2e/m^2$) |
|---|---|---|
| Results | City Quay – new building (stages A1-A5) | 468 |
| Benchmarks | ILFI Target (stages A1-A5) | <500 |
| | LETI 2020 target (stages A1-A5) | <600 |
| | Embodied Carbon Benchmark Study (stages A1-A5) | Between 200 and 500 |

## 4.2 Whole life-cycle carbon analysis

### 4.2.1 Scenario 1: Analysis using projected grid decarbonisation

#### *4.2.1.1 Scenario 1.1*

- Decarbonisation of grid based on projections (Estimated)
- The new building is assumed to have **150kWh/m2 operational energy**.

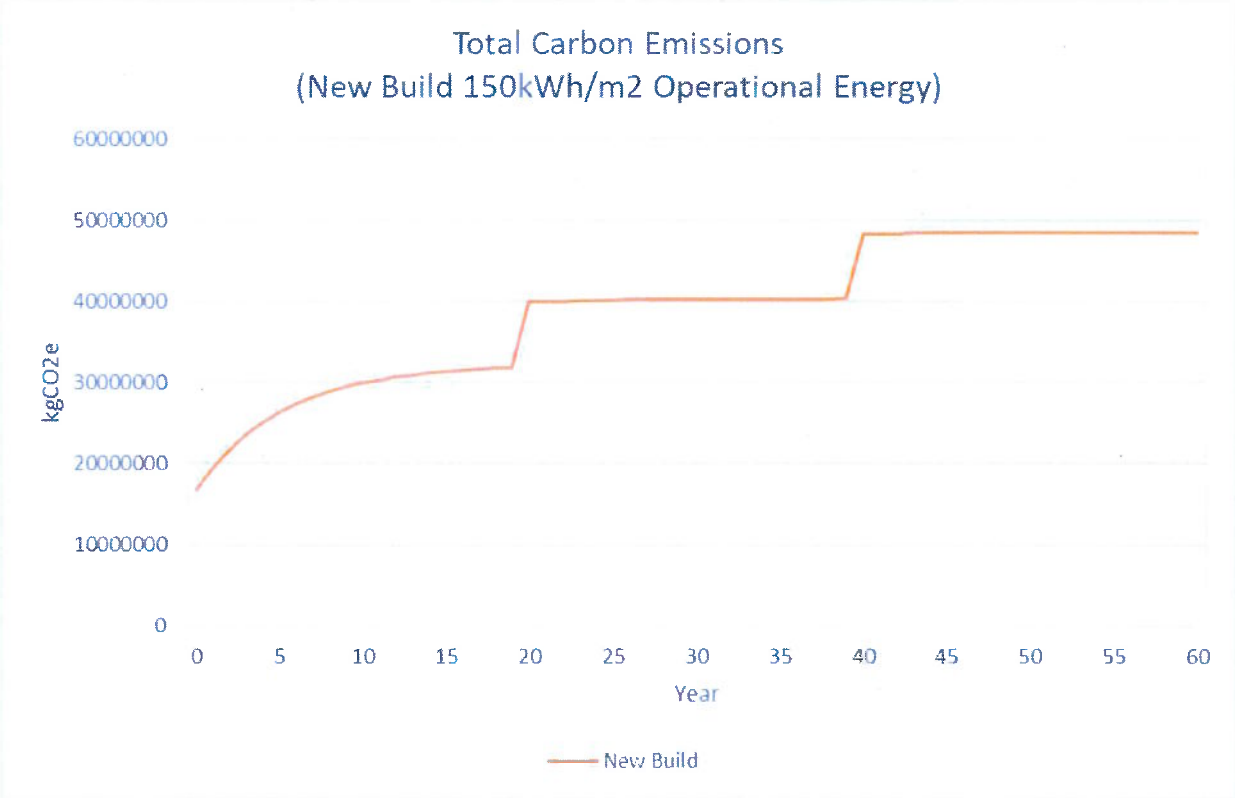


*Figure 10: Scenario 1.1- Total Carbon Emissions*

#### *4.2.1.2 Scenario 1.2*

- Decarbonisation of grid based on projections (Estimated)
- The new building is assumed to have **100kWh/m2 operational energy**.

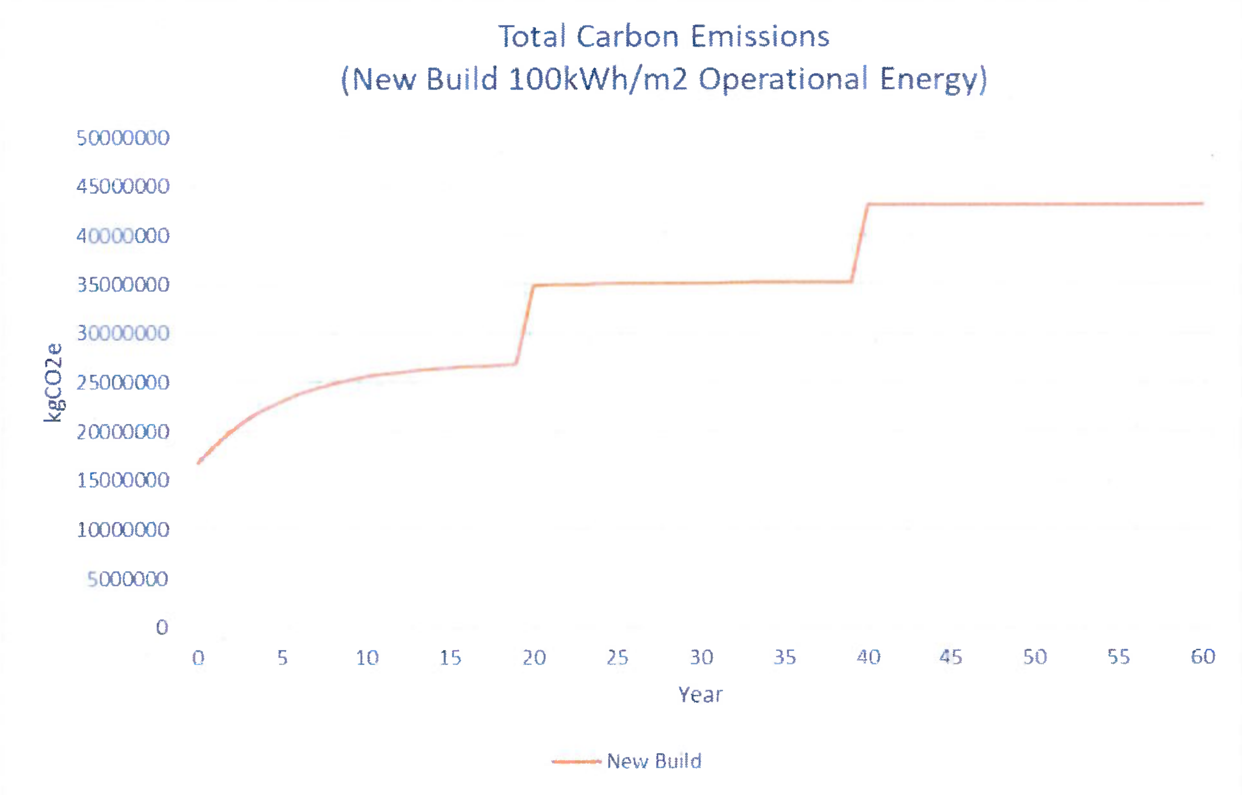


*Figure 11: Scenario 1.2 - Total Carbon Emissions*

### *4.2.1.3 Scenario 1.3*

- Decarbonisation of grid based on projections (Estimated)
- The new building is assumed to have **75kWh/m2 operational energy**.

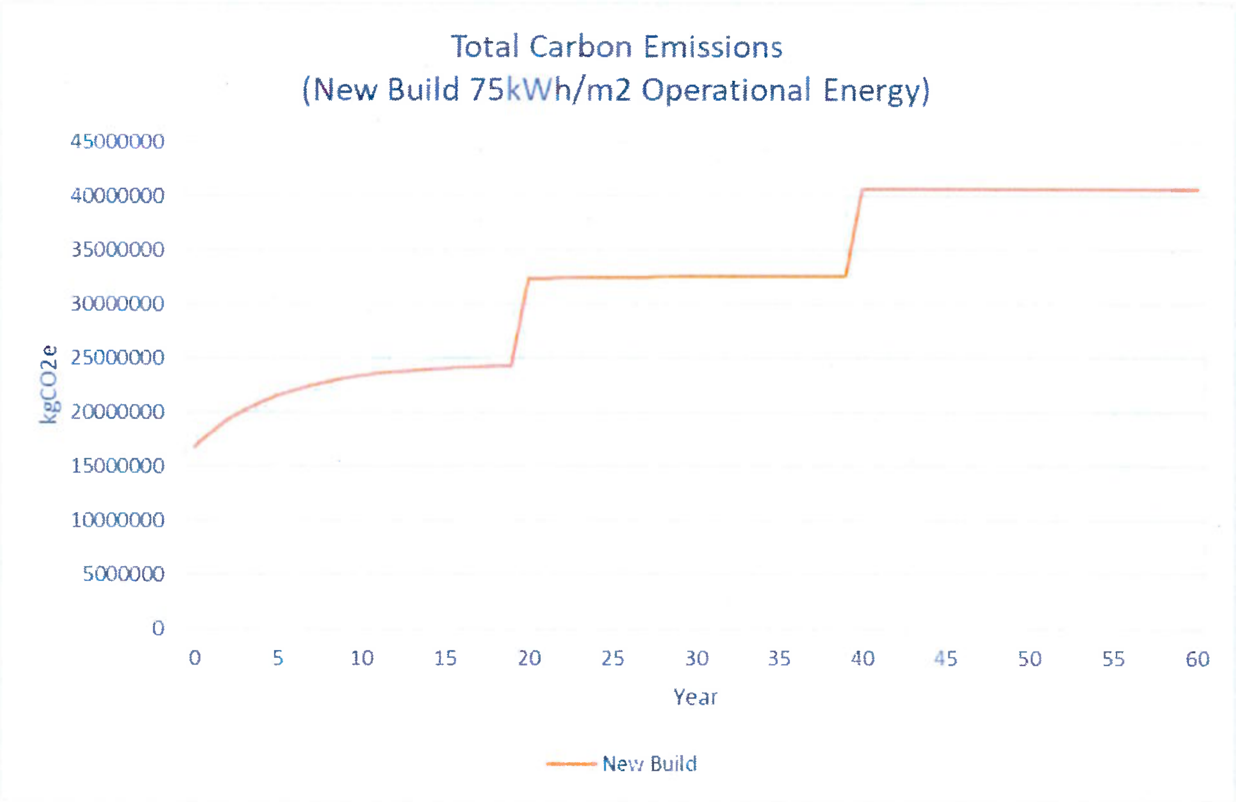


*Figure 12: Scenario 1.3 - Total Carbon Emissions*

6-8% less carbon emissions
vs New Build

### 4.2.2 Scenario 2: Analysis based on grid decarbonising slower than expected

#### *4.2.2.1 Scenario 2.1*

- Decarbonisation of grid approximately 50% slower than estimated projections (of scenario 1.)
- The new building is assumed to have **150kWh/m2 operational energy**.

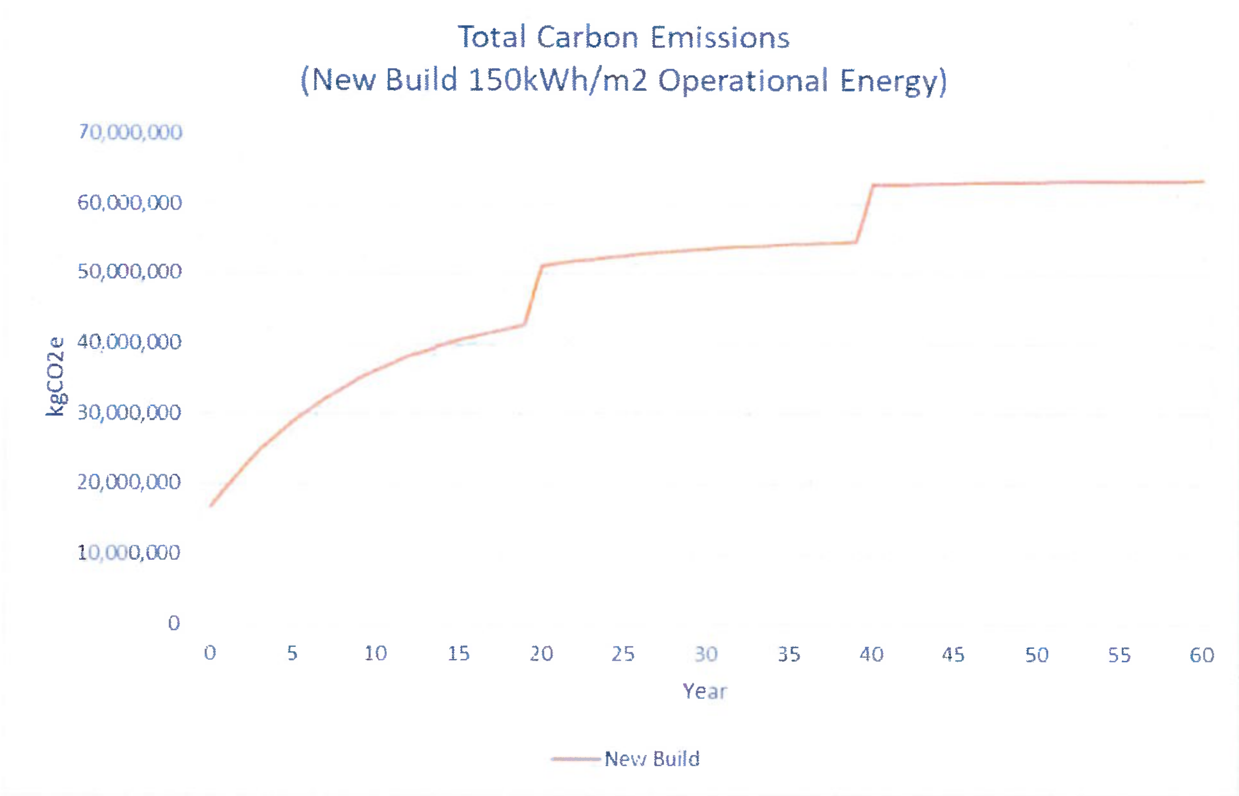


*Figure 13: Scenario 2.1- Total Carbon Emissions*

#### *4.2.2.2 Scenario 2.2*

- Decarbonisation of grid slower than estimated projections (of scenario 1)
- The new building is assumed to have **100kWh/m2 operational energy**.

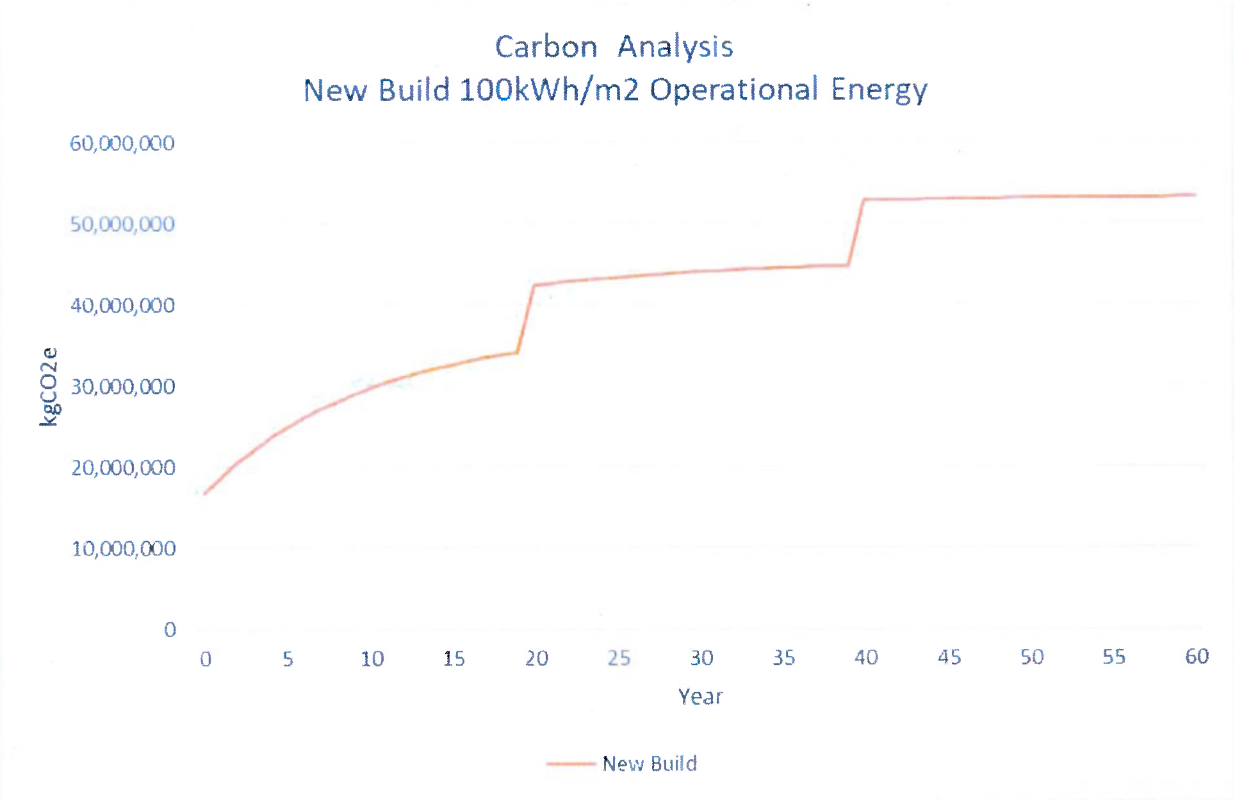


*Figure 14: Scenario 2.2- Total Carbon Emissions*

### *4.2.2.3 Scenario 2.3*

- Decarbonisation of grid slower than estimated projections (of scenario 1)
- The new building is assumed to have **75kWh/m2 operational energy**.

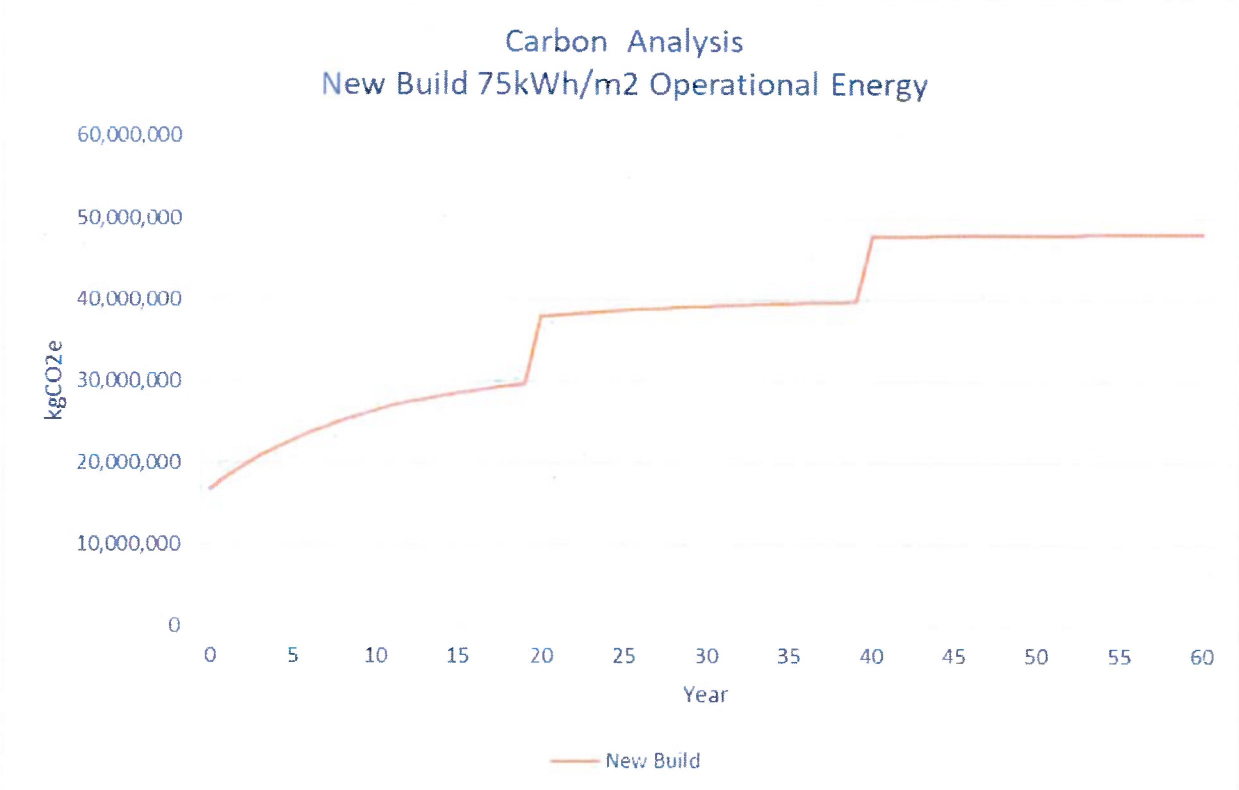


*Figure 15: Scenario 2.3- Total Carbon Emissions*

### 4.2.3 Summary

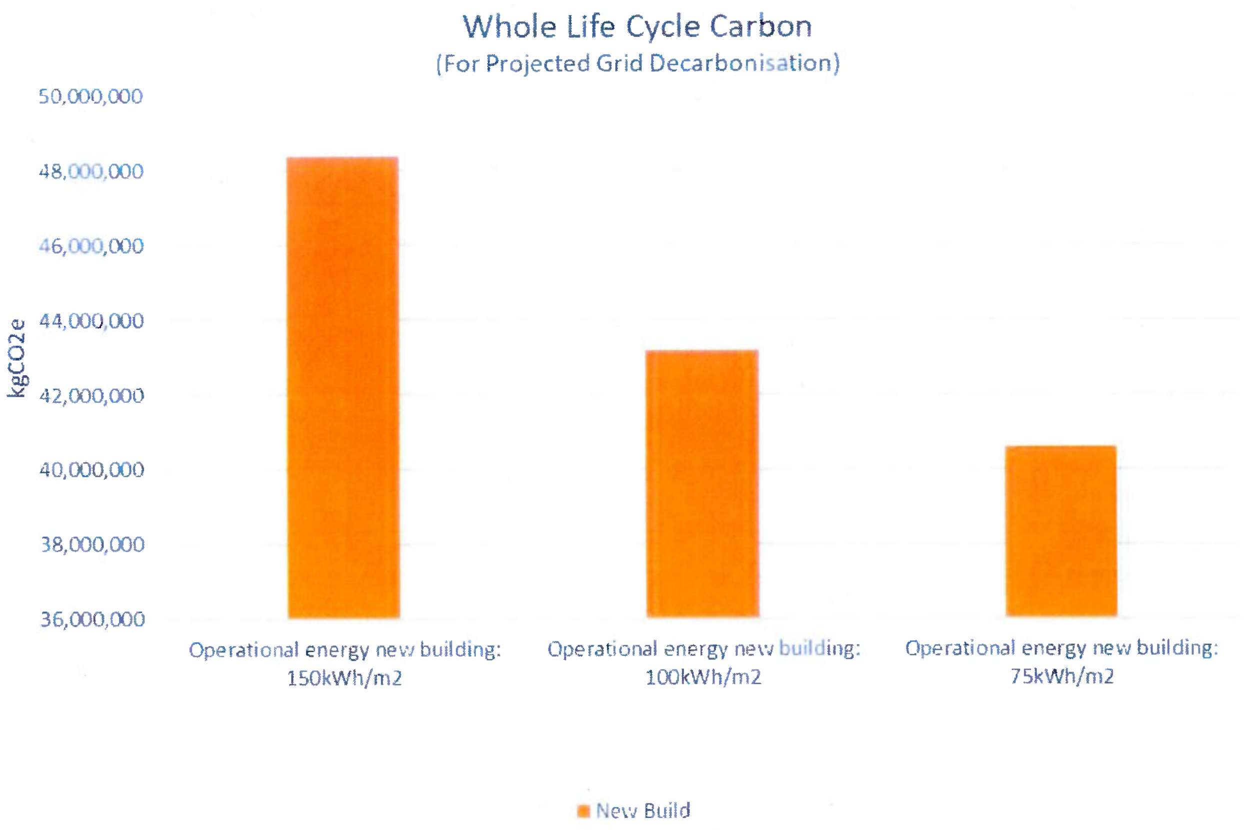


*Figure 16: Whole Life Cycle Carbon emissions- using estimated grid decarbonisation*

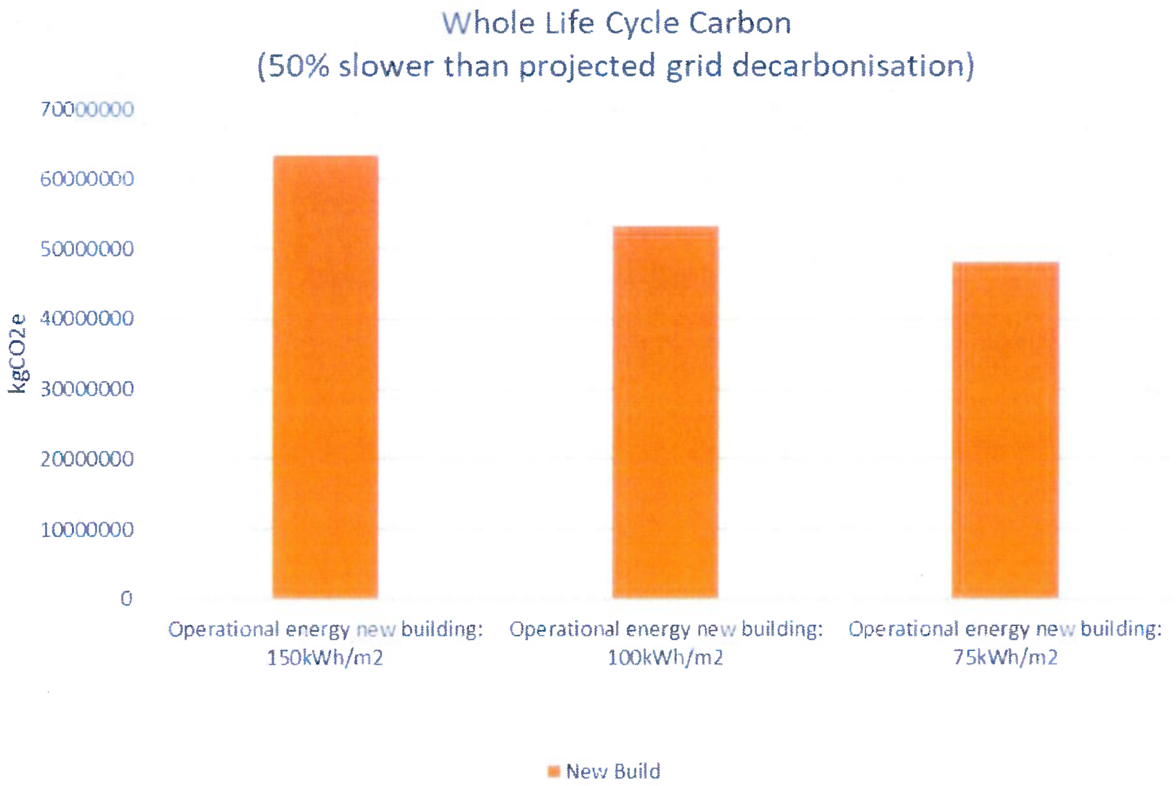


*Figure 17: Whole Life Cycle Carbon emissions - (With 50% slower grid decarbonisation than Scenario 1)*

# 5 Conclusion

This assessment reviewed the whole life-cycle carbon assessment performed for the demolition of the existing disused former City Arts Centre Building and construction of a 24 storey mixed use building containing an arts centre, office and café accommodation, and exhibition performance space. The total embodied carbon emissions for Upfront Embodied Carbon and Whole Life Embodied Carbon over a period of 60 years were found to be:

- Upfront Embodied Carbon = 468 kg $CO_2e/m^2$
- Whole Life Embodied Carbon = 705 kg $CO_2e/m^2$

These results are in line with the current benchmark values presented in Section 4.1.2.

The analysis also shows the relationship between the total whole life-cycle carbon emissions and the operational energy consumed by the building over 60 years considering two grid decarbonisation scenarios.

This assessment should provide the design team with a good starting point to assess embodied carbon reduction strategies such as alternative low carbon materials and assemblies. It is important to bear in mind that although carbon is only one of many considerations that need to be taken into account when designing a building, the embodied carbon can be reduced significantly by careful design and procurement.

# Appendix A OneClick software details

The software holds 11 third party certifications and complies with over 30 certifications and standards for Life Cycle Assessment and Life Cycle Costing, including all versions of LEED and BREEAM. The software includes curated and verified global and local databases. The up-to-date list of integrated databases can be found here: https://www.oneclicklca.com/support/faq-and-guidance/documentation/database/.

One Click LCA has been third party verified by ITB for compliance with the following LCA standards: EN 15978, ISO 21931-1 and ISO 21929, and data requirements of ISO 14040 and EN 15804. The full compliancy documentation is available at https://www.oneclicklca.com/support/faq-and-guidance/documentation/compliancy-and-certifications/.

All of the datasets in the tool comply with ISO 14040/14044 and most part also EN 15804 standard.

All building Life Cycle Assessments delivered by the One Click LCA platform comply with the following International Standards:

| | |
|---|---|
| ISO 14040 | Environmental management. Life cycle assessment. Principles and framework |
| ISO 14044 | Environmental management -- Life cycle assessment -- Requirements and guidelines |
| ISO 21930 | Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services |

One Click LCA platform tools used in European context comply with following European Standards:

| | |
|---|---|
| EN 15978 | Sustainability of construction works Assessment of environmental performance of buildings – Calculation method |
| EN 15804 +A1 | Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products |
| LEED v4 | ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) 90.1-2010 defines the baseline energy model using the performance rated method (PRM). |

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