Carnegie Library, John's Quay

Whole Life Cycle Assessment Report & Energy Retrofit Capacity Report

CBRE Ireland

December, 2024

Contents

Introduction ... ii
Project details ... ii
Guidance/Policy Summary ... iv

Whole Life Carbon Assessment ... v
Operational Carbon Assessment ... v
Embodied Carbon Assessment ... xi
Results and Conclusions ... xiv

Energy Retrofit Capacity Report ... xv
Introduction ... xv
Objectives & targets ... xv
Selected measures for improved energy efficiency ... xv
Recommendations ... xviii
Next steps ... xviii

Appendix A: Key technical sustainability principles ... i

Appendix B: Whole of Life Carbon Results ... i

Version	Date	Prepared by	Checked by	Issued by
1	02/12/2024	Katie Lewis Sustainability Consultant Meltem Kocaarslan Sustainability Analyst Lorenzo De Donatis Director – Sustainability Rachael McGinley Head of Sustainability	Rachael McGinley Head of Sustainability Lorenzo De Donatis Director – Sustainability	Lorenzo De Donatis Director – Sustainability
2	16/12/2024	Katie Lewis Sustainability Consultant Meltem Kocaarslan Sustainability Analyst Lorenzo De Donatis Director – Sustainability	Rachael McGinley Head of Sustainability Lorenzo De Donatis Director – Sustainability	Lorenzo De Donatis Director – Sustainability

Introduction

The purpose of the combined reports is for the Part VIII application as part of the wider planning application for the refurbishment of the Carnegie Library in John's Quay, Kilkenny. The Quay is currently going through a period of regeneration and plans are being developed as part of the Urban Design strategy for the area.

Kilkenny County Council requires Carbon Measurement to be completed for the refurbishment of the Carnegie Library which includes the assessment of:

1. Operational Carbon Emissions, and
2. Embodied Carbon Emissions

CBRE Ireland has conducted a Whole-life Carbon Assessment (WLCA) to capture these carbon impacts and identify areas in which these effects can be reduced as part of Part VIII application process.

Kilkenny County Council also requires an Energy Retrofit Capacity Report for the Energy Efficiency Design (EED) process.

Project details

Carnegie Library is a key historic building within the premises of Kilkenny City. The detached three bay (four-bay deep) single-storey library, on a square plan with single-bay single-storey gabled end bays, was constructed between 1908-10 and opened 1910. Its location on Johns quay facing the River Nore is a focal point when viewed particularly from the other side of the river (The City Core), from Johns Bridge, the developing Abbey Quarter and the New Lady Desert Bridge.

The basis for energy upgrading works in historic building is the 'Improving Energy Efficiency in Traditional Buildings – Guidance for Specifiers and Installers' as published by the Department of Housing, Local Government and Heritage. The statutory requirements in relation to the Planning and Development Act 2000 are currently being dealt with. The building is considered a heritage building as it encompasses a number of traditional construction methods. The building at hand, however, is not entirely of the so called 'traditional construction' as it does not have solid masonry walls and suspended timber floors, but is constructed of blockwork and presumably, a solid concrete floor slab. Its roof construction, rainwater goods, internal partition walls, windows and roof lights on the other hand follow the historic building style and require a different approach.

The building is currently in RIBA Stage 3, and at Part VIII of the application process. The new floor plan will consist of a library, offices, canteen and meeting rooms. The proposed new glazed veranda will also have to comply with the regulations for traditional buildings.

Figure 1 Carnegie Library Site Layout Plan

Project elements and WLCA boundary

The Whole-life Carbon Assessment (WLCA) includes an estimation of operational carbon emissions throughout the lifespan of the building (set at a default of 60 years) as well as the embodied carbon associated with the refurbishment and maintenance of building structure and systems.

Specifically, the assessment includes:

- Operational Carbon, derived from:
    - Lighting energy usage
    - Heating, Cooling, and Ventilation (HVAC) systems energy usage
    - Domestic Hot Water (DHW) energy usage
    - Equipment/other unregulated loads based on activity and space types

- Embodied Carbon, derived from:
    - Foundations and Substructure
    - Vertical Structure and Façade
    - Horizontal Structures
    - Other Structures and Materials
    - External Areas and Site Elements
    - Building Technology

Guidance/Policy Summary

'Improving Energy Efficiency in Traditional Buildings – Guidance for Specifiers and Installers'

As published by the Department of Housing, Local Government and Heritage. The statutory requirements in relation to the Planning and Development Act 2000 are currently being dealt with. In relation to Building Control / Regulations, these requirements apply to the construction of new buildings, as well as extensions and material alterations to existing buildings. This means that the new glazed veranda has to comply with the regulations, but also new stepped / ramped access, sanitary equipment or new windows for example.

'Energy Upgrading of Traditional Buildings for Low Embodied and Life Cycle Emissions'

The report, "*Energy Upgrading of Traditional Buildings for Low Embodied and Life Cycle Emissions*," prepared by the Department of Housing, Local Government and Heritage in Ireland, outlines how to retrofit historic solid-walled structures to improve their energy efficiency while minimizing carbon emissions. It provides a review of current national and international standards, the structure of a step-by-step guidance document for heritage buildings. The report emphasizes the importance of considering both embodied and operational carbon emissions in building retrofits and highlights the potential for deep retrofits to produce significantly lower carbon emissions compared to new builds.

'BS EN 16883 European Standard provides guidelines for sustainably improving the energy performance of historic buildings'.

CSN EN 16883 This European Standard provides guidelines for sustainably improving the energy performance of historic buildings, e.g. historically, architecturally or culturally valuable buildings, while respecting their heritage significance. The use of this standard is not limited to buildings with statutory heritage designation, it applies to historic buildings of all types and ages. This European Standard presents a normative working procedure for selecting measures to improve energy performance, based on an investigation, analysis and documentation of the building including its heritage significance. The procedure assesses the impact of those measures in relation to preserving the character-defining elements of the building.

Whole Life Carbon Assessment

Whole Life Carbon Assessment (WLCA) is the comprehensive analysis of environmental impacts associated with the project life cycle from the material extraction to the production, use and its end of life.

The WLCA model follows the international standards ISO 14040 and 14044. A WLCA is an estimation of the quantity of all carbon emissions expected to be emitted over the entire life cycle of a built asset as shown in Figure 2-1.

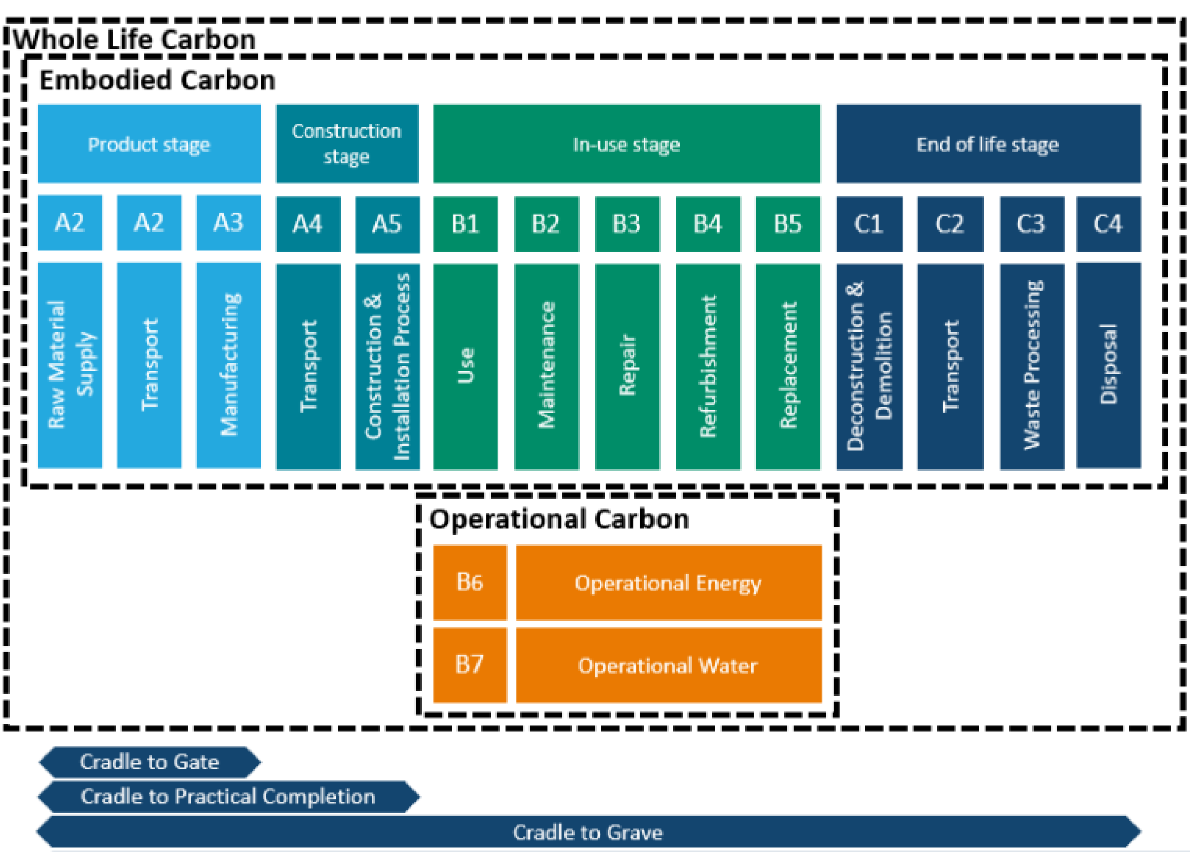

Figure 2 Building life cycle stages and information modules (adapted from EN 15978, EN 17472 and EN 15643

For this report, the carbon emissions associated with operational energy (Stage B6) were estimated using the IES Virtual Environment software, while the embodied carbon was estimated using the OneClick LCA software.

Operational Carbon Assessment

Dynamic simulation modelling was utilized to conduct a high-level assessment of operational energy consumption and carbon emissions of the baseline building. This approach provided a preliminary understanding of the building's environmental impact by integrating essential factors such as climate data, anticipated occupancy patterns, and design configurations.

Energy efficiency measures were then applied to the building within the energy modelling tool to understand their impact, guide design decisions, and foster sustainability, ensuring that carbon emissions are effectively considered from the outset of the project.

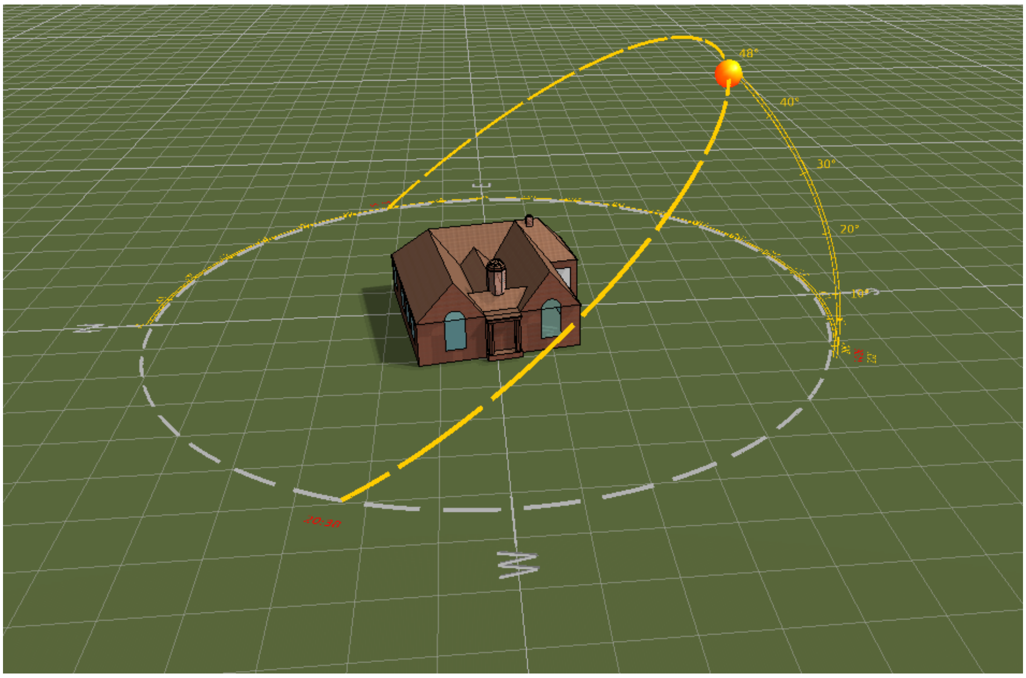

Figure 3 Carnegie Library Energy Model

Assumptions – Baseline building

The baseline building energy model has been created in the Virtual Environment software respecting the existing floor plans and sections provided. The modelling approach, at this stage, is high level and represents the main constructions, activities and systems within the building, and follows typical set points and uses of similar building types in Ireland.

Thermal characteristics of constructions, where available, have been represented accurately. Data gaps have been filled through the use of building regulations, based on the construction age of the asset.

Building heating, cooling, and ventilation (HVAC) systems are those of the actual building, however their efficiencies have been assumed based on typical values, where missing.

Table 1 gives an overview of the values used within the Baseline building energy model.

Table 1 Baseline Building Assumptions

ITEM	VALUE	SOURCE
External Walls	U-Value: 1.622	Architectural design feasibility report / Thermal calculations
Roofs	U-Value: 2.5	Architectural design feasibility report / NEAP inference procedure
Windows	U-Value: 5.5	Feasibility report / Energy Efficiency in Traditional Buildings
Ground Floor	U-Value: 1.2	Architectural design feasibility report / NEAP inference procedure

Heating system	Gas, sCOP: 0.86	Architectural design feasibility report / NEAP inference procedure
Lighting	Fluorescent	NEAP inference procedure – no lighting specified

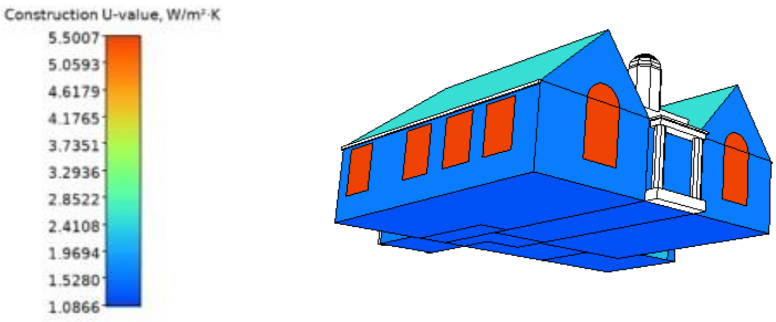

Figure 4 Existing building constructions U-Values

Energy Conservation Measures

The energy conservation measures considered for this assessment are based on those proposed within the Feasibility Report. The energy model enabled the identification of energy and carbon savings associated with the implementation of such measures, both singularly and as a whole.

An overview of the energy conservation measures is provided in Table 2 below.

Table 2 Energy Conservation Measures

ITEM	ENERGY CONSERVATION MEASURE
External Walls	Cavity insulation. New U-Value: 0.590 (Architectural design feasibility report)
Roofs	Addition of 50mm insulation. New U-Value: 0.55 (Architectural design feasibility report)
Windows	Addition of secondary glazing. New U-Value: 1.7 (Energy Efficiency in Traditional Buildings)
Ground Floor	No change
Heating System	Replace gas boiler with Heat Pump and increase radiators surface. New sCOP: 3.5
Lighting	Replace fluorescent with LED lighting (> 120 lm/W)
Renewables	Addition of 4.7 kWp of Photovoltaic (PV) panels (25 m^2) on the rooftop

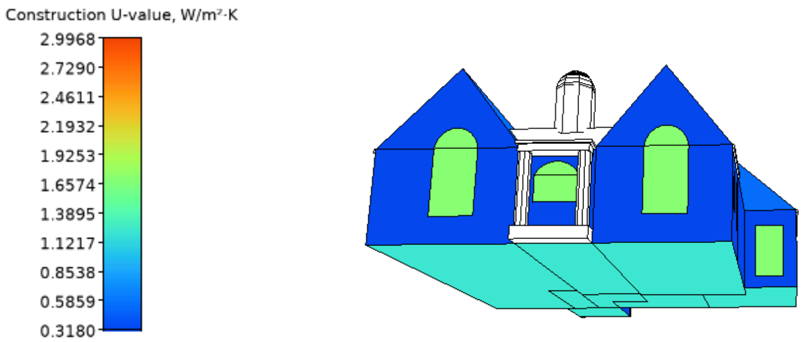

Figure 5 Proposed building constructions U-Values

Data Sources

The data for this WLCA was sourced from:

- Architect overall Feasibility Design Report
- 23K22 RMCE Carnegie Library Feasibility Report – Rev 1 documents
- Proposed Scheme architectural drawings
- Improving Energy Efficiency in Traditional Buildings Guidance for Specifiers and Installers
- Non-Domestic Energy Assessment Procedure (NEAP) methodology

Results

Operational energy usage for the Baseline building and the post-retrofit scenario have been estimated through dynamic simulation, taking into account system efficiencies, fabric thermal properties, and climate data.

The retrofit scenario shows a drastic reduction in space heating, from 69.2 to 9.1 MWh/year, which is justified by the better thermal performance of the building fabric as well as the higher efficiency of the heat pump system compared to the existing gas boiler. Lighting energy is also halved through replacement of fluorescent lights with LED bulbs.

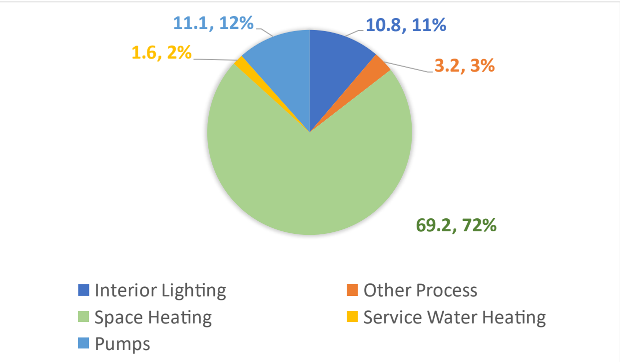

Figure 7 Baseline energy breakdown (MWh/year, %)

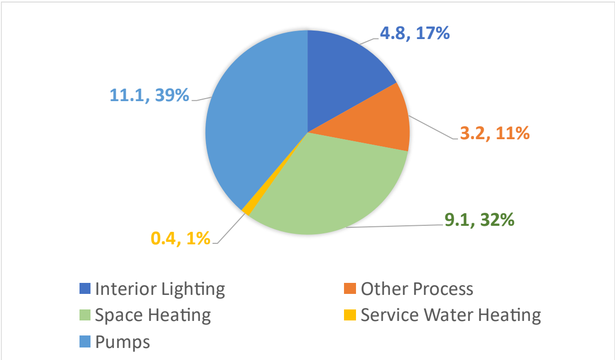

Figure 6 Retrofit energy breakdown (MWh/year, %)

From an overall energy usage perspective, the retrofit scenario can see a slight increase in electricity consumption, especially during colder months, due to the electricity needed to run the heat pump system. The natural gas is however fully phased out, helping the decarbonization journey of the building in the long term.

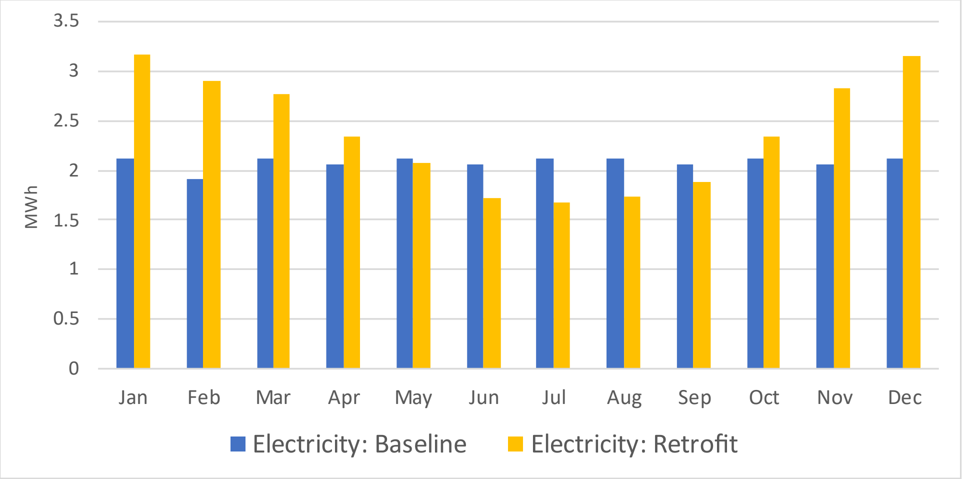

Figure 8 Baseline vs Retrofit Electricity Consumption (MWh/month)

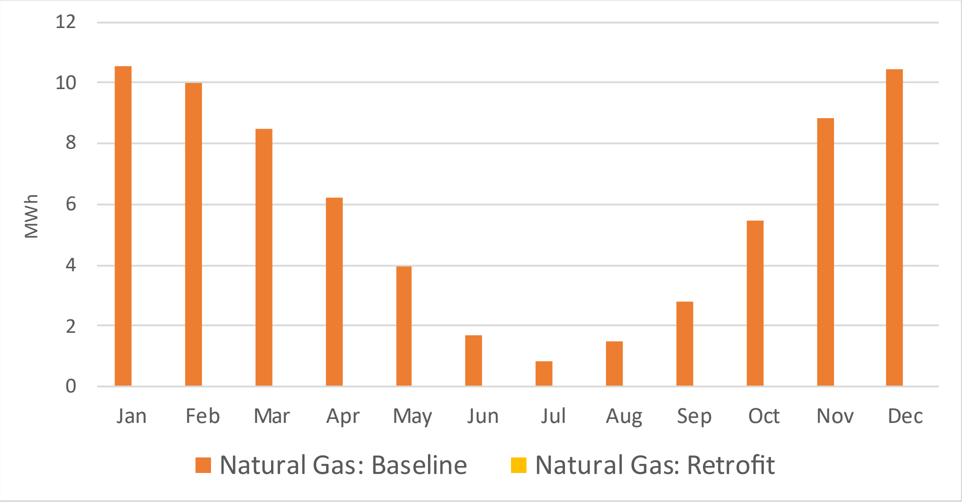

Figure 9 Baseline vs Retrofit Natural Gas Consumption (MWh/month)

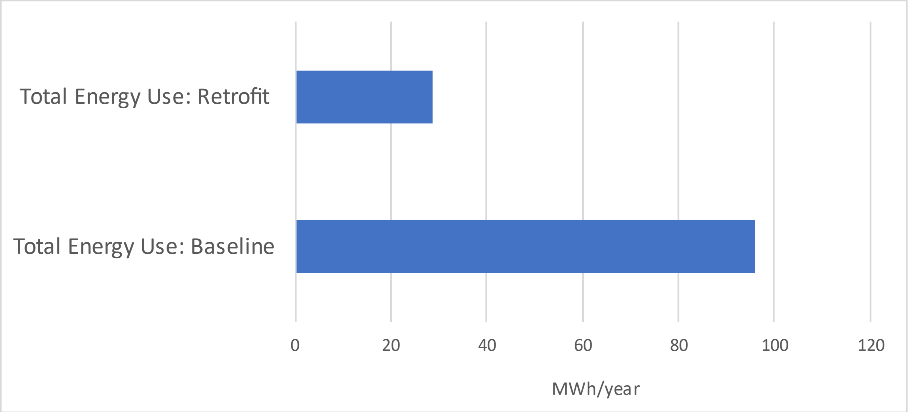

Figure 10 Baseline vs Retrofit Total Energy Consumption (MWh/year)

Finally, the contribution of Photovoltaic panels has been estimated. Given that a roof inspection and feasibility study have not been carried out, a conservative estimation has been made by only considering half of the South-facing roof surfaces covered by PV panels. This equates to approximately 25 m^2 of PVs, which corresponds to about 14 panels of 1.8m^2 each and a peak power of 4.7 kWp.

The total annual energy generation from the PVs equates to 4MWh, which would cover 14% of the retrofit building electricity demand.

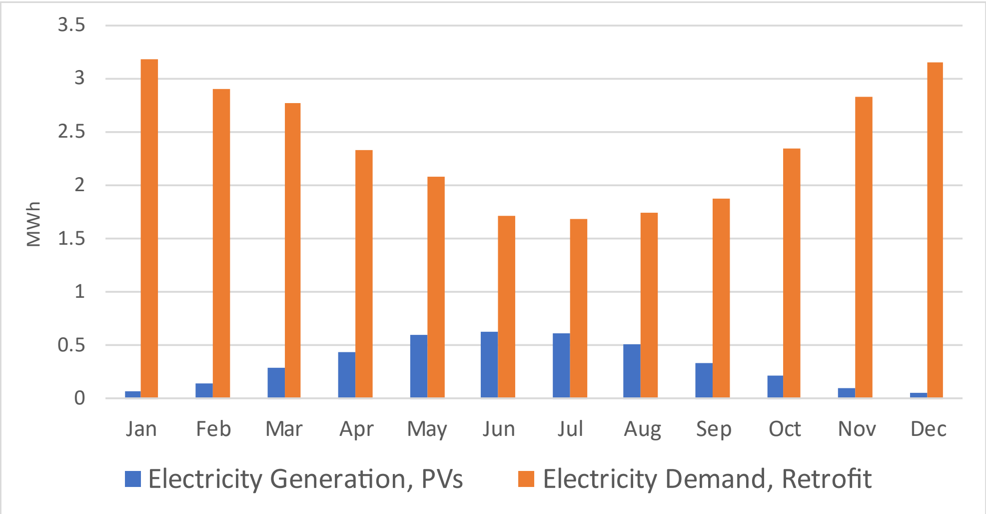

Figure 11 Electricity demand vs Generation (MWh/month)

The operational energy usage has ultimately been used to understand carbon emissions over the lifetime of the building. Current and future emission factors have been considered using the Public Spending Code 2019 predictions, which assume the electricity grid to be fully decarbonized by 2050.

Table 3 Summary of Operational Energy Assessment Results

	BASELINE	RETROFIT
Gas Demand (MWh/year)	70.81	0
Electricity Demand (MWh/year)	24.99	28.57
Electricity Generation, PVs (MWh/year)	0	3.99
Electricity from the grid (MWh/year)	24.99	24.58
Carbon emissions, 2025 (tons CO_2)	20.1	5.6
Carbon emissions 2025-2085 (tons CO_2)	936	68

Should the emission factors predicted by the Public Spending Code be met, the retrofit would achieve a 93% reduction in operational carbon emissions over the lifetime of the building, compared to a do-nothing scenario. The next step is calculating the additional carbon associated with the implementation of the retrofit measures, in order to understand if such upfront expenses are justified by the operational savings.

Embodied Carbon Assessment

OneClick LCA

One Click is an automatic LCA software that allows the user to calculate the emissions for a project and therefore reduce them. OneClick is closely aligned with guidance set out in PAS 2080 which suggests a modular structure for capturing and reporting carbon emissions according to lifecycle phase.

The associated Eco Invent Database is a globally recognised extensive database for relevant construction projects, kept up to date by BioNova. Integrating data from different stages of the project, different tasks are straightforward, and OneClick is also compatible with wider project portfolio management. Internationally recognised tool, with widespread use in numerous engineering sectors. One Click LCA aggregates results of the assessment according to the PAS 2080 modules (A1-A3, A4, A5, etc.). This is particularly useful in generating statistics that are comparable across projects and, can be easily interrogated to find the main drivers of carbon on a given project.

Assumptions

All calculations, unless stated, have been provided using the OneClick LCA tool and the Carbon Designer tool.

- Life span of the building is 60 years.
- Assumptions have been made in collaboration with the Design and Energy consultants.
- Quantities have been assumed using the Carbon Designer 3D tool for the existing materials.
- Transportation types are assumed as below until construction stage:

Table 4 Transportation Assumptions

TYPE	MATERIAL
All LGVs average laden	Paints, Sanitaryware, Vinyl products
All rigids average laden	Reinforcement, Fencing, Pavers, Below ground drainage, Asphalt, Aggregates, Ready Mix Concrete
All Articulated average laden	Precast concrete items, Main steel items, Façade panels, Plasterboard, Insulation, Roof lighting, Doors, Tiling, Internal lighting

Data Sources

The data for this WLCA was sourced from:

- Architect overall Feasibility Design Report
- 23K22 RMCE Carnegie Library Feasibility Report – Rev 1 documents
- Improving Energy Efficiency in Traditional Buildings Guidance for Specifiers and Installers

A benchmarking exercise was conducted in the OneClick software to validate the results against previous WLCA in the software. The results are illustrated below in Figure 3-1. The results demonstrate the WLCA results and how there have been efforts made to reduce the carbon associated with the design of the building.

The overall results from the WLCA of the Existing Conditions is 1,167 tCO2e over the lifespan of the building.

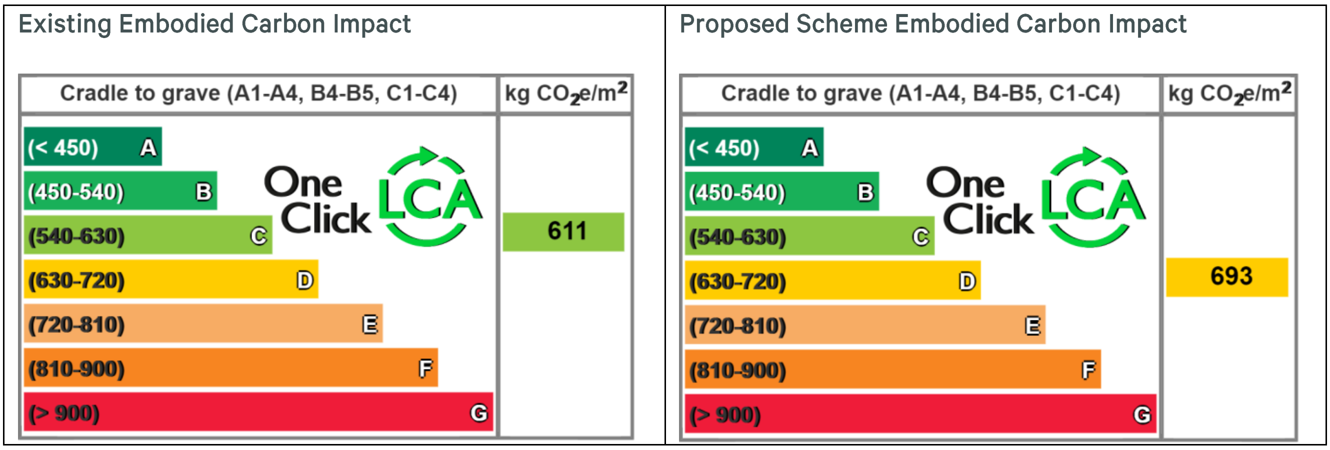

Figure 12 Embodied carbon benchmarking

Carbon Emissions by LCA Phase

The results of the WLCA are expressed through the standard phases of the project that have been outlines in Figure 2-1.

The embodied carbon that is present within the production of construction materials is where most of the carbon is present. This is to be expected on a building like this for several reasons.

- Transportation Impacts are reduced by using Irish sourced materials such as concrete.
- The bulk of materials are to remain permanently across the buildings design life, resulting in a reduced B4-B5 material replacement category.

A detailed breakdown of the materials and their carbon impact on the project is illustrated below in Table 3-1.

Table 5 Total tCO2e per project phase (60 years assumed lifecycle)

Project Phase	Existing Conditions (tCO2e)	Refurbishment (tCO2e)	% Change
A1-A5: Materials	140	152	8.5% Increase
B4-B5: Replacement	28	39	2.6% Increase
B6: Energy	936	68	93% reduction
C1-C4: End of Life	63	75	19% increase
Total	**1,167**	**334**	**71.4% reduction**

The diagrams below illustrate the impact of each phase as a proportion of the project's overall carbon emissions.

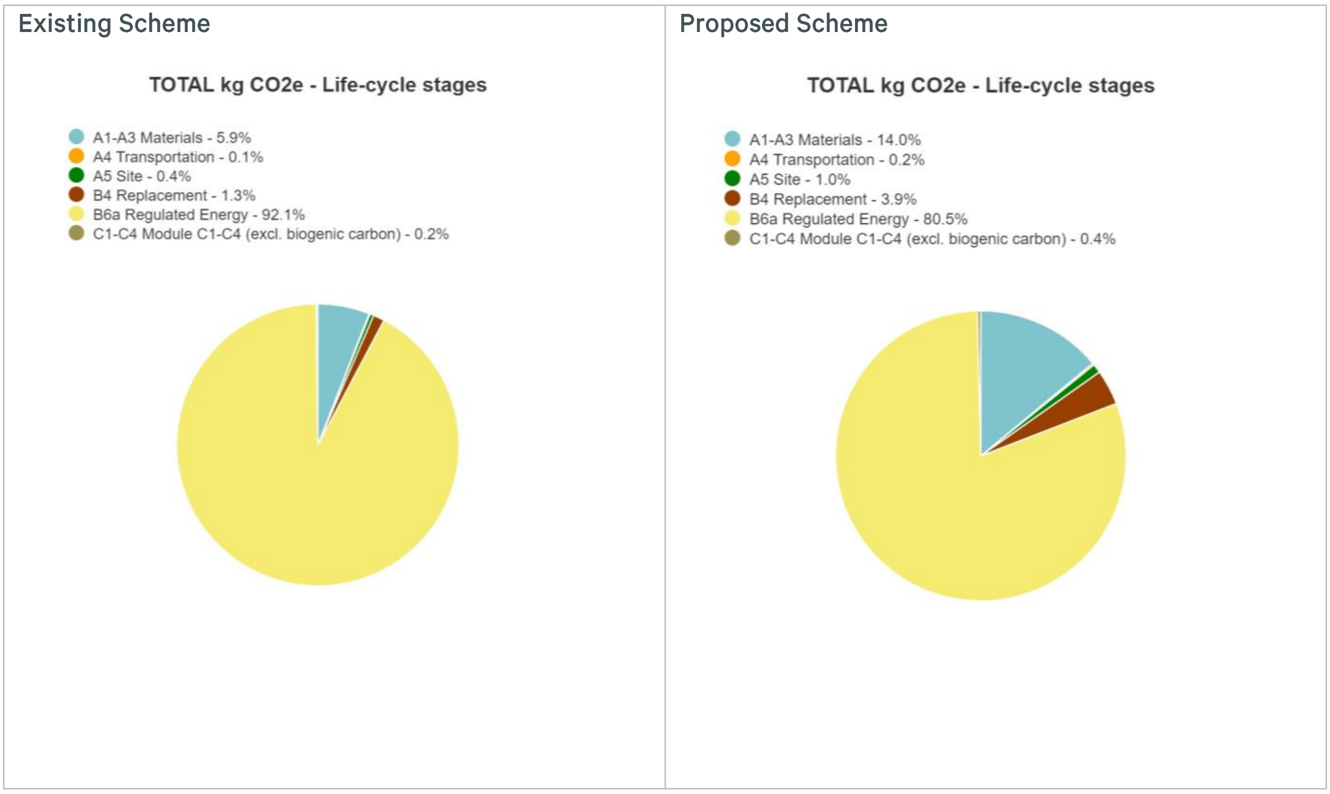

Figure 13 Carbon emissions by life cycle stages

Carbon Hotspots Renovation Materials

Table 6 provides a summary of the most carbon-intensive materials that would be used in the renovation of the building.

Table 6 Material carbon hotspots

Material or Product	% Contribution to WLC
Stone wool insulation	2.6%
Updated electricity distribution (wiring)	3.7%
PV Panels	3.5%
Heat distribution system (water from Air/water heat pump)	2.0%

Results and Conclusions

Potential Future Considerations

Given the heritage status of the building, and the requirement to comply with 'traditional building' standards, there are limitations to the additional carbon savings which could be made to the refurbishment of the building. There are however additional potential carbon savings to be made in further refining the selection of materials as the design of the development progresses. This includes:

Energy Retrofit Capacity Report

Introduction

The basis for energy upgrading works in historic building is the '*Improving Energy Efficiency in Traditional Buildings – Guidance for Specifiers and Installers*' as published by the Department of Housing, Local Government and Heritage. Below is an overview of the recommended retrofit Energy Efficiency Design (EED).

Objectives & targets

The approach of the report and the wider retrofit is to minimise the loss of historic fabric ensuring the presentation of the structure is enhanced in this important nodal area of the city, while improving the overall retrofit and energy efficiency of the building. The targets and objectives have been set against a number of key technical criteria and energy/sustainability requirements which have been included in Appendix A of this report. The adaptation and any proposed material alteration shall require compliance with current Building Regulations and provides the opportunity to enhance the existing arrangement at the facility. The report will also make recommendations in line with carbon reduction and the improvement of thermal performance in line with national obligations under the Climate Action Plan in regards to the Protected Status and Heritage value of the structure and its urban environment.

Selected measures for improved energy efficiency

Below are a summary of potential measures which have been suggested in the Architectural Design Feasibility and have been reviewed as part of the energy retrofit capacity report. The report will assess these measures and assess risk and determine risks relating to condensation, ventilation, thermal bridging and the impact of the measures on the building's heritage significance, providing mitigation measures where applicable.

Roof

It is a recommendation that the roof is stripped of its slates giving an opportunity to introduce low impact thermal intervention by way of a flexible wood fiber board installed between the rafters whilst maintaining the required roof venting. The second layer of insulation should be laid perpendicular to the first to cover any gaps. If an access walkway is required, it should be laid between supports running perpendicular to the ceiling joists to minimise thermal bridging. This can be achieved with the installation of the new slate layer with counter battening in the zone of the existing slate. It is noted that the original lath and plaster vaulted ceilings are to be protected during this re-slating work.

The installation of the insulation between rafter to sloped ceiling soffit, and on the flat for central areas is recommended; however, the risk of causing excess humidity needs to be considered. To mitigate this risk, the attic should be ventilated and the insulation has to be of hygroscopic type and have anti-mould properties, making it suitable for high-humidity environments. Mineral-based insulations tend to have higher associated embodied emissions than bio-based insulations due to the intense processing required to convert the minerals into insulation materials. They are vapour-permeable, however, which makes them suitable for use in traditional buildings.

External Walls

External insulation is not acceptable for the building due to its historic features. However, internal wall insulation may be considered. For the insulation of the walls, three options were provided within the design statement for inner wall insultation. With the understanding that the conservation preference for this building is to make use of the existing cavity for additional insulation, to minimize fabric loss and cold bridges, this option has been considered. The achievable U-value that has been used for the assessment is of 0.590 W/m^2K.

The proposed insulation will improve the thermal performance of solid walls but may, if not carefully specified, detailed and executed, introduce significant moisture-related risks. This measure will lead to a greater temperature differential between the external masonry wall and the internal finishing. It is therefore particularly important that the insulation is vapour-permeable to allow any moisture to dissipate. By providing a breathable internal wall insultation board (Gutex Thermoroom) combined with diatomite (vapour barrier) inner lining to the walls, issues surrounding moisture can be mitigated. This will require preparation of the wall surfaces and removal of non-breathable layers to prevent moisture related risks

To maximise insulation in the widows, vacuum insulation panels may be considered for window / door reveals where the existing non-historic windows are being replaced in the lobby to a historic glazing pattern. Where the existing non-historic glass panes are to be replaced, vacuum-insulating double-glazed panes should be considered to reduce the overall window U-value and increase the surface temperature of the glass surfaces.

Plumbing

Surface-mounted conduits/pipework should be installed when upgrading the heating system within the building. Surface mounted pipework minimises visual impact on heritage features. Discreet service placement and removal of services from wall elevations to align with conservation principles should be integrated into the M&E design of the renovation.

Windows & lay-lights

The windows and laylights are an integral part of the overall interpretation of the building. The same principles can be applied to the windows and laylights. Each (while repeated) is a unique piece of joinery craft contributing to the overall Craftmanship of the building. The windows and laylights should be carefully renovated with no physical alterations, as this would have large implications for the building's heritage. The intervention of secondary glazing should retain the function of the existing windows. It is proposed as part of the thermal interventions to fit a bespoke slim profile secondary sash to the inner reveal of the window which can provide significant U-value improvements and can be reversible from a conservation perspective.

New double-glazed windows may be installed in the lobby, however, to fit in with the historic glazing pattern. vacuum-insulating double-glazed panes should be considered to reduce the overall window U-value and increase the surface temperature of the glass surfaces. This vacuum insulation measure may have an impact on existing natural ventilation provisions, and additional mechanical ventilation measures may be required to mitigate both general and extract ventilation issues. Historic single-glazed timber framed fixed lay-light, with central hinged section for manual ventilation – to be kept in-situ. The Installation of 'secondary' glazing, e.g., external fixed roof-light to appropriate design should be considered to further improve the U-value. While there are limitations for the end user as it compromises comfort, as the secondary glazing will improve the U-value and the historic integrity of the building is not compromised, it is considered a viable option to improve the energy efficiency of the refurbishment. This is also of key importance when considering the installation of a heat pump for space heating, which will struggle to reach optimal performance curves with the existing fabric.

Floors

The floors consist of a solid concrete floor slab which cannot be insulated without removal, as this will result in changing the building fabric which cannot be tampered with. Where historically significant floors are present, consideration should be given to achieving the improved thermal performance required through introducing vertical edge insulation at the plinth externally. Internally edge insulation can be concealed under skirtings or finishes. A registered thermal modeler will be required to assess the resulting U-value to apply to the floor.

Heating

The existing radiators (and associated covers) are of no historic value; However, underfloor heating is not practicable without replacement of the solid concrete floor slab, therefore cannot be integrated into the building design. The recommended technology to be installed is an air source heat pump. However, to determine whether a building is suitable for heating using a heat pump, the building's Heat Loss Indicator (HLI) requires to be calculated. The average HLI of a building constructed in 1920 is 4.24[1]. In the instance the HLI for the building is too high, a high water temperate/ larger heat pump for the building may be considered if the building's HLI is above the threshold of 3. The installation of inter-wall insultation however should provide a building with a more comparable u-value to make it more suitable for the installation of a heat pump.

Ventilation

The building is currently naturally ventilated, with passive vents in situ at the following locations: circular ceiling vents to the internal spaces - two gable wall vents, the open cupola to the front and a tin roof vent to the rear roof ventilating the attic space. It needs to be considered if the ventilation requirements from those are in line with minimum ventilation rates (Part F Building Regulations). If so, it is advised to at least enable manual closing/opening of the vents which are currently in situ.. Alternatively, if budget/space allows, then they can be closed altogether and mechanical ventilation can be installed. This report however has assumed natural ventilation will remain as part of the HVAC services, either through the existing vents or through decorative metal grilles. It is recommended in all buildings where airtightness is below 3m3/(m2.h) at 50Pa, mechanical ventilation is installed (Technical Guidance Part L), as increased airtightness can lead to a build-up of unhealthy levels of moisture and other indoor airborne pollutants. As heritage buildings generally baseline above this target air tightness factor, further considerations should be made to the installation of further mechanical ventilation systems to align with this building regulation requirement.

Lighting

While lighting has not been included as part of the Design feasibility, while no data is currently available on the current age of existing general lighting, the renovation of the building will require lighting older than 15 years old to be upgraded (Technical Guidance Part L). However, the replacement of existing light fittings with LED light fittings can achieve significantly lower operating temperature and should be considered as part of the wider project for reducing whole life carbon. Changes to lighting systems also are low impact from a building fabric perspective.

Renewables

PV panels have been suggested within the design feasibility report for the building to supplement the running of the heat humps and to connect to the new electrical services. As the Carnegie library is a protected structure and there are no outer buildings/other buildings on site which could support the installation of these panels, the installation of PVs for the building can be challenging according to the guidance for Energy Efficiency in Traditional Buildings. However, Planning and Development Act (Exempted Development) (No.3) Regulations 2022 (S.I No.493 of 2022) and wider guidance provided by Kilkenny Council in regard to section 5 of the act state Planning Permission provides a number of exemptions, though these exemptions do not discount the requirement for planning to be sought for

[1] Based on analysis of SEAI BER Public Search Data by Irishheatpumps.com. Values are approximate.

protected structures. Section 5 provides guidance, stating planning can be sought for the installation of solar technology on a protected structure. Where solar arrays could be positioned in a way in which they will not have an excessively adverse impact on the landscape, either individually or in combination planning permission may be granted. While ideally PVs should be South-facing to optimize their performance, the rear side of the building could be considered as an alternative if this would help minimizing visual impacts.

Recommendations

Following an analysis of the proposed building energy upgrades and with guidance from the appropriate guidelines, the selected building can tackle several measures to improve its energy efficiency.

Below is a summary of the risks highlighted and the mitigation measures that can be put in place:

- The application of PV panels has been identified as a risk, the positioning of the panels should be considered before seeking planning application to mitigate any risks with granted planning.
- Mechanical ventilation has not been considered as part of the wider design strategy but may mitigate issues identified with increased moisture. Current vents in situ should not be blocked and in line with minimum ventilation rates (Part F Building Regulation).
- Secondary Glazing should be considered which is easily removable by the end user and is a further measure to improve the U-value without compromising the integrity of the building.
- Discreet service placement and removal of services from wall elevations to align with conservation principles. Surface-mounted conduits/pipework should be installed to minimise impact on existing fabric.
- While insultation to the external wall cannot be considered, internal wall insulation which provides the highest U-value is recommended resulting in the lowest U-value, to maximise the efficiency of low energy technologies. Alternative insultation may be considered but will have an impact on the U-value of the building.

Next steps

To align with the objectives & targets as set out earlier within the report, the recommendations should be incorporated into the retrofit design. However, when considering the recommendations above, considerations should also be made to planning policy at the local level with support from the guidance provided for traditional buildings. Specialist consultants will be required to be appointed as necessary (e.g. heritage impact assessment, thermal bridge modelling, condensation risk assessment) to mitigate any risks and potential measures indicated within the report at the design stage. The appointment of specialist consultants is also important at the construction stage to ensure that no loss of historic fabric is incurred because of upgrading the building fabric and services. The appointment of specialist consultants at specific milestones within the project is also pivotal to the sustainability accreditation as referenced in Appendix 1 of the report.

Appendix A: Key technical sustainability principles

Below is an overview of the key consideration for the building in terms of conserving the building for and its implications on the outcome of the targets & objectives as outlined within the energy retrofit capacity report, and its wider impact on key sustainability issues in relation to sustainability accreditations.

Key applicable sustainability issue	UN SDG's	General Principles for conserving the building	Key considerations for the proposed energy upgrades in terms of Sustainability accreditation
Management	9 Industry, Innovation and Infrastructure	Windows These are historic single-glazed timber casement windows, much of the historic glazing survives – replacement with double-glazing is not acceptable (loss of historic fabric, but also not achievable due to glazing panel sizes.	Where the components that can be specified are limited due to the heritage requirements, it is acceptable to exclude this from the Life Cycle Costing. Windows will not require to be included in the LCC in this instance, reducing the value.
			Stakeholder engagement must encompass legislative requirements, e.g. local building regulations, heritage requirements. Third-party groups should also be consulted as part of sustainability accreditation requirement.
Materials	12 Responsible Consumption and Production 9 Industry, Innovation and Infrastructure	Windows These are historic single-glazed timber casement windows, much of the historic glazing survives – replacement with double-glazing is not acceptable (loss of historic fabric, but also not achievable due to glazing panel sizes.	Material efficiency. For heritage buildings and buildings in a local or national conservation area, measures to protect vulnerable parts of the building from damage (criterion 1) and to limit material degradation (criterion 2) should be based on the measures that are feasible within the scope of any heritage requirements that may be explicitly required by the relevant conservation authority (e.g. the local authority heritage office). This should consider the range of options that may be feasible in order to demonstrate compliance with justification provided, including reference to documentary evidence to verify any restrictions that are in place that prevent compliance with any durability measures.

Transport	11 SUSTAINABLE CITIES AND COMMUNITIES	No energy retrofit capacity elements applicable to the sustainability issues.	
Land use	15 LIFE ON LAND	No energy retrofit capacity elements applicable to the sustainability issues.	
Waste	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Floors presumably solid concrete floor slab – cannot be insulated without removal, which is not acceptable (loss of historic fabric).	Recycled aggregates will not be applicable to this job, and credits can be awarded provided an explanation is given.
Pollution	14 LIFE BELOW WATER 13 CLIMATE ACTION	Existing radiators (and associated covers) are of no historic value.	Heat pump can be considered as existing radiators of no historic value. Thus, NOX emissions are low and Pollution credits may be awarded.
Health & wellbeing	3 GOOD HEALTH AND WELL-BEING	Ventilation - Mechanical system in place, incl. decorative ceiling vent covers – to be kept in situ, even if not re-used	Mechanical ventilation needs to be retained or improved, and as aligned with Indoor Air Quality Plan.
		Windows - These are historic single-glazed timber casement windows, much of the historic glazing survives – replacement with double-glazing is not acceptable (loss of historic fabric, but also not achievable due to glazing panel sizes)	Thermal modelling required except where alternative performance standards are required by a local or national conservation body or authority. Heating systems should be modelled for continuous heating rather than intermittent.
		Lay-lights - Historic single-glazed timber framed fixed lay-light, with central hinged section for manual ventilation – to be kept in-situ, even if not re-used.	In some cases an explicit requirement from the relevant historic buildings conservation authority (e.g. local authority conservation officer) may require the retention of heritage features which prevents zoning of lighting in accordance with criterion 13 . In such cases, evidence should be provided from the conservation officer and measures should be considered to ensure that adequate control is provided for existing retained lighting zones and measures adopted for the provision of task lighting as relevant for the function type and as is feasible within the constraints as applied by the conservation officer.

Energy		Heating - Existing radiators (and associated covers) are of no historic value. Under floor heating not practicable.	
		Installation of 'secondary' glazing, e.g., internal casement windows to appropriate design may be considered.	Low energy design: Under some circumstances an LZC feasibility study may be undertaken. However, due to heritage building consent or local planning regulations in a heritage conservation area, there may be no recommendations that can be implemented. In this situation, this may be compliant with criteria 7 and 8 provided it can be demonstrated that a wide range of options have been considered with consultation input from the local authority conservation or heritage officer, e.g. considering options for locating LZCs out of public view etc. and the report contains evidence to support these findings.
		Walls External insulation not acceptable (loss of historic character), internal lining can be of modern material (phenolic / PIR insulation), i.e., breathability is not required Internal lining will inevitably lead to areas of cold-bridging, e.g., floor to wall junction, window / door reveals, wall to roof junction.	The design team has demonstrated that the cold store and the building has been designed to minimise heat loads through high levels of insultation etc. At least 50% of the recommendations incorporated in the Energy Efficiency Design (EED) report above should be incorporated into the design of the project.

Appendix B: Whole of Life Carbon Results

Below table is the result for the whole life carbon assessment according to RICS methodology, EN 15978 and Greater London Authority guidance for whole life-cycle carbon assessments.

Table B1: Existing Building

	Biogenic carbon (kg CO2e)	A1-A3 Product Stage	A4 Transportation to site	A5 Site operations	B1 Use Phase	B2 Maintenance	B3 Repair	B4 Material replacement - materials	B5 Material refurbishment	B6 Operational Energy use - Regulated	C2 Waste transportation	C3 Waste processing	C4 Waste disposal	TOTAL kg CO2e	D External impacts (not included in totals)
1 Substructure	0	3555.57	224.85	171.87			0				95.56	372.38		4420.23	-534.32
2.1 Frame	0	9275.72	359.2	420.84			0				267.07	23.1		10345.93	-2259.9
2.2 Upper Floors	0	6812.23	36.44	621.21			0				200.51	12.7		7683.1	-1210.89
2.3 Roof	-60310.2	44033.32	220.41	4312.37			0	2688.73	0		257.05	61407.77	28.09	52637.54	-106.58
2.4 Stairs & Ramps															
2.5 Ext. Walls	0	41338.22	1157.72	3170.82			0				827.78	93.5	2.24	46590.29	-5351.53
2.6 Windows & Ext. Doors	-382	2464.09	3.9	30.15			0	783.4	0		33.41	386.31	0.073	3319.34	-521.13
2.7. Int. Walls & Partitions	0	3398.09	113.38	467.5			0				144.4	17.07		4140.44	-1096.71
2.8 Int. Doors															
3 Finishes	0	58.62	0.28	5.9			0	295.11	0		0.067	0	0.06	360.04	
4 Fittings, furnishings & equipment															
5 Services (MEP)	0	18625.51	35.6	196.8			0	24503.49	0	2008581	134	11.96	1.75	2052090	-17845.3
6 Prefabricated															
7 Existing building															
8 Ext. works															
Other or overall site construction				0										0	
Unclassified / Other															
TOTAL kg CO2e	-60692.2	129561.4	2151.77	9397.48			0	28270.73	0	2008581	1959.85	62324.79	32.21	2181587	-28926.4

Table B2: Proposed Building

	Biogenic carbon (kg CO2e)	A1-A3 Product Stage	A4 Transportation to site	A5 Site operations	B1 Use Phase	B2 Maintenance	B3 Repair	B4 Material replacement - materials	B5 Material refurbishment	B6 Operational Energy use - Regulated	C2 Waste transportation	C3 Waste processing	C4 Waste disposal	TOTAL kg CO2e	D External impacts (not included in totals)
1 Substructure	0	3531.84	223.12	170.8			0				94.83	372.3		4392.89	-530.21
2.1 Frame	0	9102.97	352.51	413.01			0				262.09	22.67		10153.24	-2217.82
2.2 Upper Floors	-1180.35	7216.19	39.37	653.49			0				200.86	1192.95	1.68	8124.18	-1201.58
2.3 Roof	-66493.6	48549.03	243.01	4754.58			0	2964.5	0		283.41	67703.75	30.97	58035.61	-117.51
2.4 Stairs & Ramps															
2.5 Ext. Walls	-3751.5	42751.73	1163.1	3287.4			0				832.93	3844.9	7.57	48136.14	-5341.46
2.6 Windows & Ext. Doors	-382	3223.23	5.23	37.99			0	1566.81	0		55.61	386.46	0.072	4893.4	-535.95
2.7. Int. Walls & Partitions	0	3382.89	112.87	465.41			0				143.75	16.99		4121.92	-1091.83
2.8 Int. Doors															
3 Finishes	0	58.62	0.28	5.9			0	295.11	0		0.067	0	0.06	360.04	
4 Fittings, furnishings & equipment															
5 Services (MEP)	0	23849.56	39.48	193.25			0	35095.43	0	814973.4	150.11	13.41	1.86	874316.5	-20370.9
6 Prefabricated															
7 Existing building															
8 Ext. works															
Other or overall site construction				0										0	
Unclassified / Other															
TOTAL kg CO2e	-71807.5	141666.1	2178.97	9981.82			0	39921.85	0	814973.4	2023.67	73553.44	42.21	1012534	-31407.3