Part 1

Decarbonising Camden's Existing Buildings

A technical evidence base for planning policy

December 2024 | Rev F

Camden

Currie & Brown

Etude

Introduction

Purpose of the study

Introduction

Reducing operational and embodied carbon emissions in buildings is one of the key priorities of Camden's Climate Action Plan and is part of the borough's commitment to achieve its Net Zero Carbon targets for existing buildings by 2030.

Camden Council commissioned Etude and Currie & Brown to develop the *Camden Existing Buildings Evidence Base*, which is split up into two parts:

- Part 1 is the technical evidence base for Local Plan policies aiming at reducing existing buildings' operational energy use and carbon emissions.
- Part 2 is the technical evidence base for policies aiming at addressing and reducing the embodied carbon impact of basement construction.

Methodology

This study employed predictive energy modelling using the TM54 methodology and Passive House Planning Package (PHPP) version 10.4a in order to estimate building performance for different retrofit and extensions scenarios.

The study provides valuable data on energy use, heating demand and the associated carbon savings and capital cost implications of targeted retrofit measures carried out alongside refurbishments and redevelopments.

This evidence will be critical to inform the development of policy policy. It will help to demonstrate that its requirements are technically feasible and indicate their likely approximate costs.

This document

PART 1

Decarbonising Camden's existing buildings

Technical evidence base for policies aiming at reducing existing buildings' operational energy use and carbon emissions.

PART 2

Embodied carbon impact of basement extensions

Technical evidence base for policies aiming at addressing and reducing the embodied carbon impact of basement construction.

Opportunities for the Local Plan to enhance existing buildings for a Zero Carbon Camden

Opportunities for low carbon retrofit in Camden

The Draft Camden Local Plan 2024 addresses energy use and carbon reduction with the aim of putting existing buildings on track towards Net Zero Carbon by 2050, or earlier.

National permitted development rights have been greatly extended, so fewer types of work require planning permission. Planning policy may therefore focus as much on setting strategic aims rather than regulating restrictions. This evidence base presents an opportunity to create a significant shift to enable retrofit and set better standards to align with net zero targets.

Many applications also seek planning permission for a significant retrofit, external alterations or plant. There are therefore opportunities to encourage changes or have tailored policy in a manner that allows applicants to prioritise the retrofit measures which represent the best fit and have the most impact in the context.

While it may be challenging to account for all aspects of good retrofit practice in policy, this study aims to demonstrate that energy efficiency improvements, alternatives to fossil fuel heating and renewable energy generation are both possible and appropriate. Encouraging widespread adoption of these solutions is key.

This initiative is part of a broader strategy to ensure Camden has enough decent, safe, warm, and family-friendly housing to support its communities while contributing to the borough's 2030 zero carbon target.

Energy and cost modelling form the core of this evidence base. The findings from the modelling will inform the Local Plan Proposed Submission Draft – Regulation 19.

APPLICATION_NUMBER	APPLICATION_TY	RECEIVED_D	DECISION_	Address	Description	Full planning?	DECISION_TYPE
2019/4835/P	Full Planning Permis	23/09/2019	24/08/2022	269 Camde	The erection of a first floor rear extension to add 2 additional bedroom units to the existing first and second floor 4-bed House in Multiple	y	Granted Subject to a Section 106 Legal Agreement
2019/5015/P	Full Planning Permis	30/09/2019	18/11/2022	5 Camden R	Excavation of single basement floor to form ancillary space to the use of the ground floor (sui generis use)	y	Granted Subject to a Section 106 Legal Agreement
2019/5783/P	Full Planning Permis	15/11/2019	03/08/2022	2 Swain's La	Demolition of existing buildings. Erection of 3 storey building with retail (Class E) at ground floor and 2x1bed flats and 1x2bed (C3) above	y	Granted Subject to a Section 106 Legal Agreement
2019/6378/P	Full Planning Permis	23/12/2019	04/05/2022	7 John Stre	Change of use of a Grade II listed building from an office (Class B1) and a residential flat (Class C3) to a single family dwelling house (Class C	y	Granted Subject to a Section 106 Legal Agreement
2020/0625/P	Full Planning Permis	07/02/2020	13/07/2022	20 Vicar's R	Demolition of existing dwelling and construction of two new residential dwellings (C3).	y	Granted Subject to a Section 106 Legal Agreement
2020/1025/P	Full Planning Permis	02/03/2020	16/06/2022	Boncara35	Demolition of existing dwelling house and erection of new 3 storey single dwelling house with basement. Refurbishment of retained Listed s	y	Granted Subject to a Section 106 Legal Agreement
2020/2165/P	Full Planning Permis	18/05/2020	10/06/2022	14A Hamps	Retrospective erection of single storey lower ground floor rear extension and patio enclosed with railings. Retrospective alterations to front	y	Granted
2020/3043/P	Full Planning Permis	09/07/2020	27/03/2024	52 Tottenh	Demolition of existing building and redevelopment to provide affordable workspace, and residential units. [For consultation purposes only	y	Granted Subject to a Section 106 Legal Agreement
2020/4673/P	Full Planning Permis	12/10/2020	20/09/2023	2 Early Mew	Demolition of existing single storey lock-up shed building and erection of a 2 storey mews residential property.	y	Granted Subject to a Section 106 Legal Agreement
2020/5187/P	Full Planning Permis	11/11/2020	16/11/2022	14 & 14AH	Part retrospective alterations to rear garden landscaping including excavation and proposed replacement of artificial grass with planting [RE	y	Granted
2020/5865/P	Full Planning Permis	17/12/2020	25/05/2022	58A Fellow	Erection of single storey rear extension, excavation to create a basement with front and rear lightwells and associated works	y	Granted Subject to a Section 106 Legal Agreement
2020/5867/P	Full Planning Permis	17/12/2020	28/10/2022	The Hall Sch	Demolition of the 'Centenary' and 'Wathen Hall' buildings and erection of new four storey building with glazed link to original school buildi	y	Granted Subject to a Section 106 Legal Agreement
2020/5974/P	Full Planning Permis	23/12/2020	26/07/2022	5B Prince A	REVISIONS RECEIVED: Demolition of existing dwelling and construction of replacement dwelling with basement and associated landscaping	y	Granted Subject to a Section 106 Legal Agreement
2020/5976/P	Full Planning Permis	23/12/2020	07/04/2022	29A Gonda	Extension of existing basement for ground/basement flat, formation of new front and central lightwells.	y	Granted
2021/0686/P	Full Planning Permis	12/02/2021	04/05/2022	219 Goldhu	Erection of a 2 storey rear extension with lightwell, following the demolition of the existing single storey rear addition.	y	Granted
2021/0877/P	Full Planning Permis	24/02/2021	07/12/2022	155 & 157	Demolition of existing building and redevelopment to provide a part 4 storey/part 7 storey building, with two basement levels, for a 59 bed	y	Granted Subject to a Section 106 Legal Agreement
2021/1327/P	Full Planning Permis	19/03/2021	16/11/2022	St Christop	Erection of single storey extension to two existing classrooms and erection of link extension to existing plant building, installation of PV pa	y	Granted Subject to a Section 106 Legal Agreement
2021/1362/P	Full Planning Permis	22/03/2021	06/09/2022	Coach Hou	Erection of a rear roof extension, raised parapet to front elevation, alterations to fenestration and installation of sliding vehicle gate to front	y	Granted
2021/1527/P	Full Planning Permis	30/03/2021	25/01/2023	31 Elswort	New basement extension to include a pool and rear lightwell, alteration and retention of balconies at second floor rear, alterations to windo	y	Granted Subject to a Section 106 Legal Agreement
2021/1538/P	Full Planning Permis	30/03/2021	05/01/2023	Flat 1st and	Erection of mansard roof extension and rear extension at second floor, all to flat.	y	Granted
2021/1586/P	Full Planning Permis	01/04/2021	04/05/2022	13 Regent's	Excavation of single storey basement, erection of front extension at lower ground level, recladding of existing ground floor extension and o	y	Granted Subject to a Section 106 Legal Agreement
2021/1600/P	Full Planning Permis	01/04/2021	02/06/2023	14 Provost	Erection of a single storey rear extension, a garden outbuilding with pergola, roof extension over the side passage and replacement side do	y	Granted
2021/1773/P	Full Planning Permis	13/04/2021	23/11/2022	68 Churchw	Erection of a mansard roof extension (resulting in creation of additional storey) for extension to a community based space for the Islamic C	y	Granted
2021/1895/P	Full Planning Permis	20/04/2021	15/11/2023	12 Netherh	Erection of single storey extension at roof level to infill the valley roof, incorporating vent stacks and rooflights, plus installation of new do	y	Granted Subject to a Section 106 Legal Agreement
2021/1919/P	Full Planning Permis	21/04/2021	28/04/2022	63 Fortess	Erection of a single storey rear second floor extension and alterations to the rear and side fenestration associated with the conversion of th	y	Granted Subject to a Section 106 Legal Agreement
2021/1991/P	Full Planning Permis	26/04/2021	06/04/2023	36 Estelle R	Erection of dormer window to rear roof slope	y	Granted
2021/2024/P	Full Planning Permis	27/04/2021	12/04/2022	92 Southan	Erection of an extension to create 11 guestrooms at basement, ground and first floor level, 2 of which are duplex to replace existing meetin	y	Granted
2021/2075/P	Full Planning Permis	29/04/2021	12/04/2023	Flat Ground	Excavation of basement extension under the footprint of the property and associated lightwells at the front and side rear of the property	y	Granted Subject to a Section 106 Legal Agreement
2021/2410/P	Full Planning Permis	14/05/2021	17/01/2024	40 Leighton	External alterations including basement excavation and rear extension with front lightwell and railings, installation of bifold crittall doors an	y	Granted Subject to a Section 106 Legal Agreement
2021/2793/P	Full Planning Permis	08/06/2021	11/10/2023	5 Templew	Conversion of 3 existing units to provide 2 units (C3); erection of rear extension with terrace above and part replacement side extension; in	y	Granted Subject to a Section 106 Legal Agreement
2021/2824/P	Full Planning Permis	10/06/2021	17/07/2022	Flat 216 Ly	Extension and alterations to existing side conservatory and ground floor terrace, including the installation of an external staircase with blac	y	Granted
2021/2840/P	Full Planning Permis	11/06/2021	05/05/2022	Flats C and	Erection of full-width, single storey rear extension in connection with the conversion of 2 residential units at ground floor level into a single	y	Granted
2021/2946/P	Full Planning Permis	16/06/2021	20/06/2023	Flat 1, 190	Erection of basement extension ancillary to existing flat	y	Granted Subject to a Section 106 Legal Agreement
2021/2983/P	Full Planning Permis	18/06/2021	20/07/2022	Flat 1, 5 De	Erection of single storey ground floor infill extension at rear of property.	y	Granted
2021/3018/P	Full Planning Permis	21/06/2021	20/03/2024	Land to the	Demolition of the existing single storey buildings (Class B2) on the site and the erection of a four storey residential block (Class C3) to prov	y	Granted Subject to a Section 106 Legal Agreement
2021/3033/P	Full Planning Permis	21/06/2021	12/04/2022	Flat Ground	Erection of an outbuilding in the rear garden.	y	Granted
2021/3374/P	Full Planning Permis	12/07/2021	12/04/2022	7 The Grov	Conversion of 2x self-contained dwellings (No. 7 and 7B) to form a single dwelling (Class C3); erection of single storey side extension follow	y	Granted
2021/3586/P	Full Planning Permis	26/07/2021	28/07/2023	25 Goodge	Erection of a single storey extension at roof level and installation of metal railings to enclose the new roof terrace at fourth floor level.	y	Granted
2021/3605/P	Full Planning Permis	26/07/2021	23/06/2022	Flat A225 G	Erection of single storey rear extension at ground floor level.	y	Granted
2021/3673/P	Full Planning Permis	29/07/2021	15/06/2022	85 Grays In	Erection of a three storey infill extension at first floor to fourth floor levels, installation of fume extract and mechanical plant at roof level, in	y	Granted Subject to a Section 106 Legal Agreement
2021/3722/P	Full Planning Permis	02/08/2021	10/08/2022	27 Lady So	Erection of a single storey rear extension at lower ground floor level (with partial excavation of rear garden ground levels) and alterations to	y	Granted Subject to a Section 106 Legal Agreement
2021/4003/P	Full Planning Permis	18/08/2021	01/02/2023	77 Avenue	Demolition of existing dwelling and erection of replacement three-storey detached dwelling with basement	y	Granted Subject to a Section 106 Legal Agreement
2021/4005/P	Full Planning Permis	17/08/2021	09/11/2023	Flat 29 Hea	Erection of a single storey side extension and formation of enclosed outdoor common area at first floor level.	y	Granted
2021/4029/P	Full Planning Permis	19/08/2021	14/06/2023	Flat A, 7 Ag	Erection of (joint) single storey side/infill and rear extensions	y	Granted Subject to a Section 106 Legal Agreement
2021/4048/P	Full Planning Permis	19/08/2021	21/07/2022	35 Dynham	Erection of dormer extension on rear roofslope with formation of terrace with metal railings on flat roof of two storey rear extension. Instal	y	Granted
2021/4211/P	Full Planning Permis	31/08/2021	29/04/2022	Maisonette	Construction of a part single part two storey rear extension at lower and ground floor level following demolition of exisiting rear conservato	y	Granted
2021/4220/P	Full Planning Permis	31/08/2021	12/04/2022	Basement F	Erection of a single storey rear extension with rooflight above and aluminium doors to rear and with lowered rear garden level.	y	Granted

All apps | Basements | Householders | Additional homes | Floorspace increase | Full planning | +

Figure 0.1 – Snapshot overview of planning applications submitted to Camden from 2019 to date

Overview of report structure

Sections	Description
Importance of retrofit	This section outlines the importance and benefits of retrofit as well as a number of key considerations.
Planning policy context	This section outlines national commitments, building regulations, and the National Planning Policy Framework. It includes a review of regional policies and guidance (e.g. London Plan, GLA Energy guidance, London Net Zero 2030 Pathway) and explores Camden's policy and guidance to encourage low carbon measures, referencing existing retrofit policies and guidance.
What factors influence retrofit?	This section highlights various retrofit measures, emphasises the importance of a whole-building retrofit plan, and examines factors influencing retrofit decision-making. It also provides a summary of the main types of retrofit work in Camden and whether planning consent is required.
Methodology	This section details the building typologies modelled as part of this evidence base, and summarises scenarios, energy modelling outputs, and benchmarks for evaluating retrofit outcomes.
Technical feasibility	This section outlines the predictive energy modelling results for the various retrofit and extensions scenarios for each typology explored.
Cost analysis	This section details the likely cost associated with the various retrofit and extensions scenarios for each typology explored.
Key findings	This section provides an overview of the key findings for each typology and scenarios. It also provides indicative quantified recommendations on potential space heating demand and energy use intensity requirements.

Contents

Glossary

Air Handling Units (AHUs) - key component of mechanical ventilation systems responsible for supplying, extracting and often heating/cooling air to a building.. AHUs typically include fans, heating/cooling coils, filters, dampers, and sometimes humidifiers or dehumidifiers. They maintain desired indoor temperature, humidity levels, and air quality standards in commercial buildings, hospitals, schools, and industrial facilities.

Air source heat pump (air-to-air) - a heating and cooling system using electricity to extract heat from the outside air and provide warm directly into the building. It can also be used in reverse mode to provide cooling.

Air source heat pump (air-to-water) - a heating system using electricity to extract heat from the outside air and heats water for use in radiators, underfloor heating systems, and domestic hot water.

Carbon budget - the cumulative amount of greenhouse gas emissions permitted over a period of time to keep within a certain temperature increase.

Carbon offsetting - the framework of financing projects to reduce CO_2 emissions with money collected through the purchase of carbon credits.

CIBSE - the Chartered Institution of Building Services Engineers (CIBSE) is an international professional institute representing building services engineers.

CIBSE TM54 - a technical memorandum from CIBSE providing a methodology to assess operational energy performance during the design phase. It considers factors like occupancy patterns and equipment efficiency.

Combined heat and power (CHP) - a system which generates electricity and heat. These systems are usually gas-fired and therefore not low carbon.

Coefficient of Performance (COP) - a ratio that compares the amount of useful heat or cooling energy produced by a system to the amount of energy input required to generate that output. It is a dimensionless value that provides a measure of a system's efficiency

Continuous Mechanical Extract Ventilation (cMEV) – a system which extracts air continuously from wet rooms (bathrooms and kitchen). Fresh air is often provided by trickle vents.

Decarbonisation - the process of reducing or eliminating carbon dioxide (CO_2) emissions. The ultimate goal is a transition towards an economy and society that produces minimal or zero carbon emissions.

Direct electric heating – a system that uses electricity directly to heat a room (i.e. without a heat pump) converting electrical energy into thermal energy through electrical resistance. These systems provide heat directly at the point of use, without the need for a central heating unit or distribution system.

EDSL Tas - a dynamic building simulation modelling software used to analyse thermal performance and energy use of building design. It enables users to create detailed 3D models and conducts hourly timestep simulations of various scenarios to optimise building features such as insulation and building services.

Electrification - the process of replacing technologies that use fossil fuels (coal, oil, and natural gas) with technologies that use electricity.

Energy Use Intensity (EUI) - a building's energy use as a function of its floor area, typically expressed as energy consumption in kWh/m2.yr. The floor area is generally expressed as Gross Internal Area (GIA).

Glossary

Fabric Energy Efficiency (FEE) - a measure of the efficiency of the building fabric at reducing the amount of energy required to heat or cool a home used in Part L 2021 of the Building Regulations.

Fabric first approach – an approach to building design and refurbishment that prioritises improving the performance of the components and materials that make up the building fabric (e.g. insulation, windows) over the introduction or replacement of mechanical or electrical systems (e.g. heat pump).

Fan Coil Units (FCUs) – building services devices which consist of a fan and a coil with hot or cold water. Air is being circulated through the coil to heat or cool areas within a building. FCUs can be ceiling-mounted or floor-mounted and are commonly used in hotels, apartments, and offices for localised temperature control.

Future Home Standard (FHS) – the next version of Part L of the Building Regulations, set to replace Part L 2021 and due to come into force in 2025.

Green buildings - also knowns as sustainable or eco-friendly buildings are buildings designed, constructed, and operated to minimise their negative environmental impact while maximising benefits for occupants and the surrounding ecosystem throughout their entire life cycle.

GW – Gigawatt, a unit of power equivalent to a billion watts.

GWP – Global Warming Potential is an index used to measure and compare the heat-trapping ability of different greenhouse gases in the atmosphere relative to carbon dioxide (CO_2)

Heat Pump - a device that uses electricity to transfer thermal energy from a heat source to a heat sink (e.g. the ground to a house). There are many varieties of heat pump e.g. air, ground and water source heat pumps. The first word in the title refers to the heat source from which the pump draws heat.

kW – kilowatt, a unit of power equivalent to a thousand watts.

kWh – kilowatt-hour, a unit of energy equivalent to one kW of energy being used or generated for 1 hour.

Low Energy Transformation Initiative (LETI) - a voluntary network of individuals across the built environment. Responsible for researching and publishing many guidance documents, including Climate Emergency Design Guide.

Low carbon heat - heating systems and technologies that produce significantly fewer carbon dioxide emissions compared to traditional fossil fuel-based heating methods. These systems aim to provide space heating and hot water for buildings while minimising their environmental impact and contribution to climate change.

Mechanical supply and extract ventilation – ventilation systems that actively manage indoor air quality by supplying fresh air while extracting stale air. Unlike natural ventilation, mechanical supply and extract ventilation systems ensure consistent air flow regardless of external conditions, making them ideal for tightly sealed buildings. These systems enhance occupant comfort and health while improving energy efficiency when equipped with heat recovery (see Mechanical Ventilation with Heat Recovery - MVHR).

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Mechanical Ventilation with Heat Recovery (MVHR) – an energy-efficient ventilation system that improves indoor air quality while minimising heating demand and therefore heating costs. It extracts warm, stale air from a building and uses its heat to pre-warm incoming fresh air. MVHR reduces heating energy needs while ensuring a continuous supply of fresh air. It is especially effective in air-tight and well-insulated buildings.

$MtCO_2$/yr - Million metric tons of carbon dioxide per year.

MW – Megawatt, a unit of power equivalent to a million watts.

MWh – Megawatt-hour, a unit of energy equivalent to one MW being used or generated for 1 hour.

Net Zero Carbon (NZC) - a 'Net Zero (operational) Carbon' building is one where no fossil fuels are used, all energy use (Module B6) has been minimised below set energy energy use limits (expressed in kWh/m2yr) and for which an equivalent amount of energy is being generated by on- or off-site renewables energy systems. It is different to the definition of 'Zero Carbon' used by the London Plan which excludes unregulated energy use and relies on carbon offsetting.

Operational carbon - emissions of carbon dioxide and other greenhouse gases during the in-use operation of a building.

Part L – Part of the Building Regulation that concerns buildings (new and refurbishments including change of use). It sets standards for their thermal performance, energy performance and carbon emissions.

PAS 2035 – a comprehensive specification for the retrofit of domestic buildings in the UK. It was developed by the British Standards Institution (BSI) as part of the UK government's efforts to improve energy efficiency and reduce carbon emissions from the existing building stock. PAS 2035 provides a standardised approach and sets out a framework for assessing, designing, and implementing retrofit projects, ensuring they are done to a high standard and deliver intended energy and carbon reductions.

Performance gap – the discrepancy between predicted energy performance during design and actual energy performance during operation. Factors contributing to the performance gap include modelling inaccuracies, construction quality issues, and occupant behaviour variations. Understanding the performance gap is crucial for improving design, construction and operation in order for buildings to deliver the intended energy and carbon savings.

Permitted development - building works and changes of use that can be carried out without the need to apply for planning permission from the local planning authority.

Primary energy - energy from fossil fuel and renewable sources that has not undergone any conversion or transformation process.

Regulated energy - building energy uses covered by Part L of the Building Regulations, including space heating and cooling, hot water, ventilation, fans, pumps and lighting.

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Renewable energy - energy derived from sources which are naturally replenished or are practically inexhaustible (e.g. sun, wind, air). They are often described as 'clean', 'green' or 'sustainable' forms of due to their minimal environmental impact compared to fossil fuels.

Retrofit - the process of making changes to an existing building so that energy use and carbon emissions are both reduced. These changes also generally lead a more comfortable and healthier building with lower energy bills.

RIBA - the Royal Institute of British Architects is a professional institution for architects primarily in the United Kingdom, but also internationally, founded for the advancement of architecture.

Solar Photovoltaics (PV) - a technology which is used to generate electricity using energy from the sun and classified as a renewable energy technology. Solar PVs are typically installed on building roofs or across large fields.

Space heating demand (SHD) - The amount of heating energy needed to heat a building to the required temperature over a year. Space heating demand is often expressed per square metre.

Standard Assessment Procedure (SAP)

Is the methodology currently used by the UK government to assess and compare the energy and environmental performance of dwellings. It is used both for Part L assessments and Energy Performance Certificates (EPCs). SAP is due to be replaced by the Home Energy Model (HEM) in 2025.

(Building) Stock - existing buildings within a defined area, such as a borough, city, region, or country. It encompasses all types of buildings, including domestic and non-domestic buildings, that have been constructed over time and are currently in use.

UKGBC - The UK Green Building Council (UKGBC) is a membership organisation which aims to 'radically transform' the way that the built environment in the UK is planned, designed, constructed, maintained and operated.

Ultra-low energy buildings - buildings that achieve ultra-low levels of energy use during their operational phase, significantly surpassing the performance standard Part L compliant buildings. An ultra-low energy building is generally defined as a building with a space heating demand of less then 15-20 kWh/m^2.yr.

Variable Refrigerant Flow (VRF) - a building services technology that allows simultaneous heating and cooling in different areas of a building using a system circulating a refrigerant fluid. It adjusts the flow of refrigerant to indoor units based on specific zone demands, enhancing energy efficiency. VRF systems are ideal for large commercial buildings, offering benefits such as reduced energy consumption, lower operational costs, and improved occupant comfort. They are a form of air-to-air heat pump.

1.0

Importance of retrofit

This section outlines the importance and benefits of retrofit as well as a number of key considerations.

Why is the decarbonisation of existing buildings important?

Decarbonising existing buildings is key to Net Zero

The vast majority of buildings that will be present in 2050 have already been built. Most of them are currently being heated by gas, are not energy efficient, and do not generate renewable energy. In order to decarbonise, it is therefore clear that most existing buildings will have to benefit from a degree of retrofit. They will use low carbon heat instead of fossil fuels for heating and hot water, become more energy efficient and comfortable, and generate more renewable energy on-site.

The electrification of existing buildings will play a pivotal role

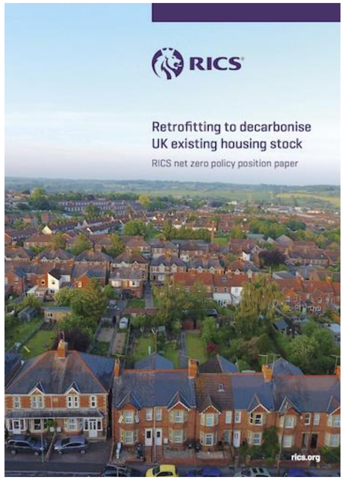
Greenhouse gas emissions associated with the generation and distribution of electricity in the UK have been reducing significantly in the last 30 years and this process is likely to carry on. This provides an opportunity for the decarbonisation of buildings: by switching away from fossil fuels (e.g. gas) for heating and hot water to electricity (a process called 'electrification') their emissions can reduce significantly and be put on track to Net Zero, i.e. the phasing out of greenhouse gas emissions between now and 2050.

Reducing energy use will benefit people and help with electrification

The capacity of the UK to generate renewable electricity is not infinite. The total demand for electricity therefore needs to be limited to the amount of energy that we can produce primarily from wind, solar energy and nuclear by 2050. This requires a reduction in energy use from existing buildings through retrofit, which will also save money on energy bills for people, businesses and other organisations.

The pace of change matters

Achieving Net Zero is not only about 2050 but also about the pace at which we will reduce greenhouse gas emissions until then (see concept of 'carbon budget'). It is therefore important for the Local Plan to support the decarbonisation of existing buildings.



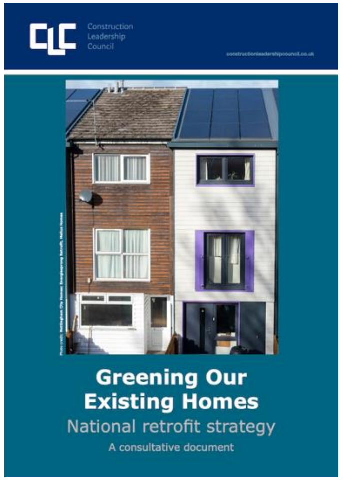


Figure 1.1 - A number of reports articulate the need and benefits of a more ambitious retrofit strategy
(Above left: Retrofitting to decarbonise UK existing stock, RICS, May 2020)
(Above right: Greening our existing homes: National retrofit strategy, CLC, December 2020)

Camden's buildings need to transition away from fossil fuels on site

Moving away from fossil fuel heating is key

The Climate Change Committee (CCC) have been very clear that the use of fossil fuels must be eliminated in virtually all buildings by 2050 for the UK to achieve the legal obligation of Net Zero.

Today, there is already less carbon emitted for every kWh of electricity delivered than there is for every kWh of gas burned. This is because of the growing proportion of renewable energy contributing to the UK electricity grid.

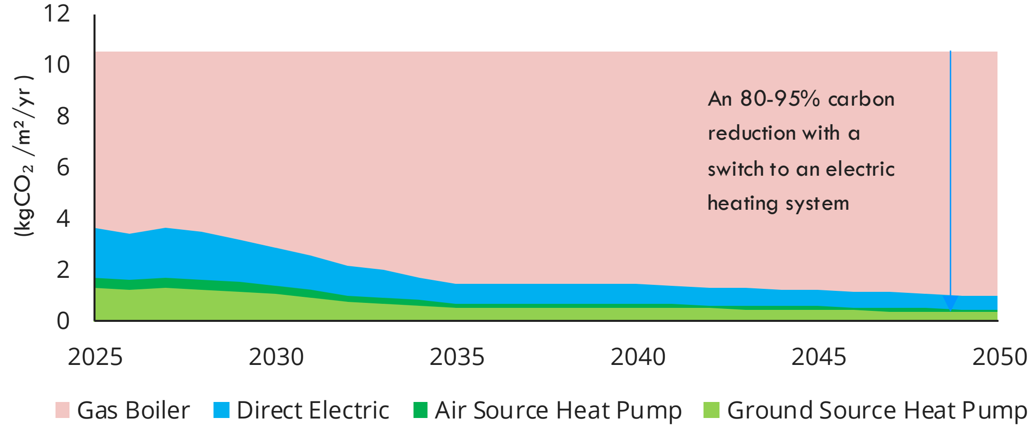
Every year the electricity generated by the grid decarbonises further to reduce our reliance on fossil fuels and shift to renewable energy resources. The Government has committed to fully decarbonise the UK's electricity grid system by 2035.

Therefore, the CO_2 emissions from electric heating systems like a heat pump using the grid electricity will continue to reduce over time, whereas the CO_2 emissions from a gas boiler will remain constant.

The number of gas boilers in buildings across the UK needs to decrease rapidly in order to meet the climate change targets.

The Local Plan needs to accelerate positive change

Retrofit policies need to grasp every opportunity possible to encourage building owners to stop using fossil fuels for heating and switch to a low carbon heating system.



Use of fossil fuels
Not compatible with Net Zero. The heating system must be changed.

Figure 1.2 - Comparison of carbon emissions associated with different heating systems or a typical home over the next 25 years.

Emissions from a gas boiler stay constant, whereas emissions from direct electric systems and heat pumps reduce over time due to grid decarbonisation. Heat pumps have lower emissions than direct electric systems purely because they are more efficient.

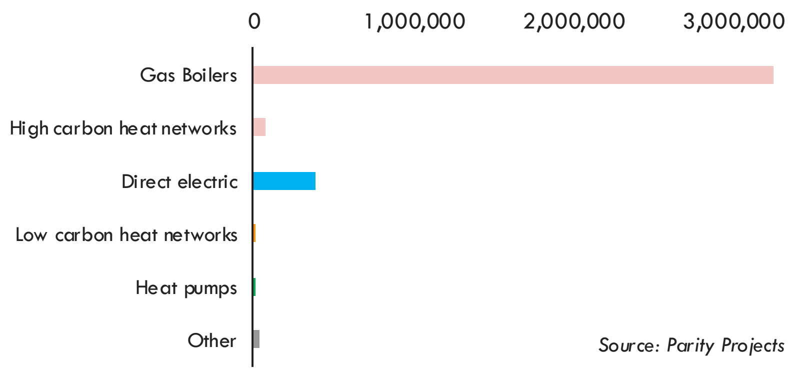


Figure 1.3 - This chart shows the current number of installations in each main heating system category in London. The move away from gas boilers is necessary but the task is significant. 'Heat networks' include both district heating systems and communal (building scale) systems. Source: Parity Projects

Retrofit depth and uptake

UK carbon budgets and renewable capacity budgets

There is a defined carbon budget for the built environment between now and 2050. In addition to this, there is a limit to the amount of renewable energy that can be cost effectively produced by the UK. This limits the renewable electricity that can be used by buildings. If this amount of electricity is exceeded, then the proportion of electricity from renewables will be reduced, which will in turn affect the carbon emissions of electricity in buildings, which will affect the carbon budgets.

Developing retrofit scenarios that meet the budgets

The energy capacity and carbon budget for existing buildings can be met through a range of retrofit scenarios. All of these scenarios will involve very significant carbon emission and energy consumption reductions between now and 2050.

The embodied carbon expenditure of retrofit needs to be considered, as well as the operational carbon reduction post retrofit.

There are various options for a borough wide retrofit strategy. This includes the speed of uptake of retrofit, the depth of retrofit and if retrofit if carried out in one go or stepped.

The deeper the retrofit, the more energy and carbon savings, but also the higher the cost of retrofit and a higher skilled workforce that is required.

One retrofit scenario could involve upgrading existing homes to a mix of medium and deep depth of retrofit. In order to meet the carbon budgets, this would require a steep retrofit uptake curve.

Alternatively, the uptake could be slower, but this would mean that a higher number of deeper retrofit would need to be carried out, (to make up for the fact that the carbon savings are happening later).

Carbon budget 2025-2050 (embodied and operational)	Renewable electricity balance from 2030/40	Proportion of UK electricity from renewables

Figure 1.4 - Related factors that need to be understood to meet UK carbon budgets

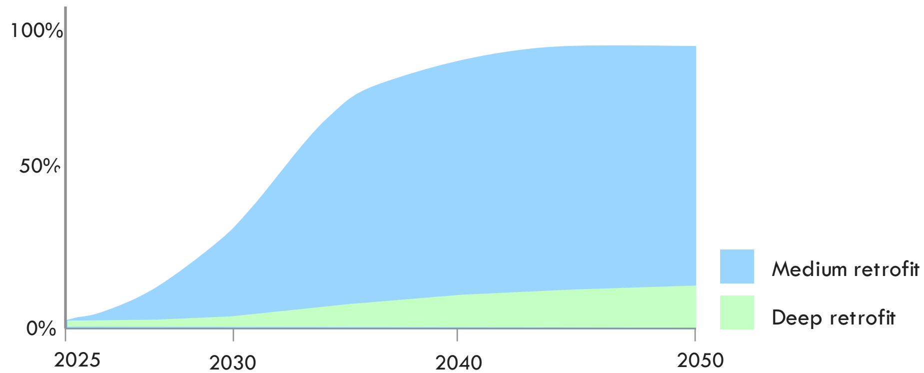


Figure 1.5 - Faster retrofit uptake, leading to higher carbon savings earlier, thus less retrofit depth required

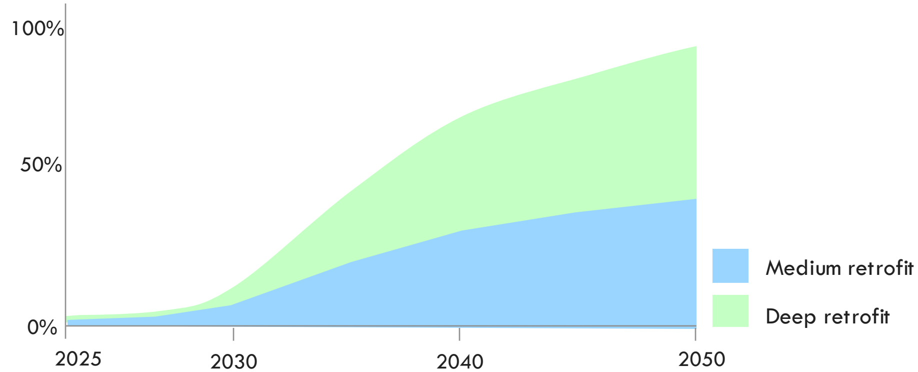


Figure 1.6 - Slower retrofit uptake, leading to lower carbon savings earlier, thus deeper retrofit depth required

Benefits of retrofit

Reducing fuel bills alongside carbon emissions

Whilst decarbonising existing buildings is important to mitigate climate change, it is not the only reason to retrofit. In 2023, 3.17 million households in England are in fuel poverty all of whom live in inefficient homes (EPC Band D or below), which represents 13.0% of all households. Retrofitting can lower energy bills and lift households out of fuel poverty. In non-domestic buildings, retrofitting also delivers immediate savings, which will save money for more useful purposes (e.g. schools, university).

Health and wellbeing

Improving a building's energy efficiency can increase thermal comfort year-round and enhance indoor air quality, benefiting everyone, especially small children, the elderly, and those with respiratory conditions. The International Energy Agency (IEA) and OECD estimate that health improvements could account for 75% of the value of energy efficiency upgrades, while poor-quality housing costs the NHS £1.4 billion annually in avoidable treatments.

Adding value and future-proofing

Retrofitting increases property value by making buildings more attractive to buyers and tenants who seek modern amenities and lower energy bills. 'The impact of retrofit on market values' report commissioned by the National Energy Foundation in 2023, suggested a 'green premium' of anything from 9.4% to 19.6%.

Future proofing the existing stock

By upgrading the fabric and reconfiguring spaces to accommodate evolving requirements and technologies, retrofitted buildings become more future proofed.

Figure 1.7 - Fuel poverty, health and wellbeing are all positive benefits of retrofit (Source: BRE)

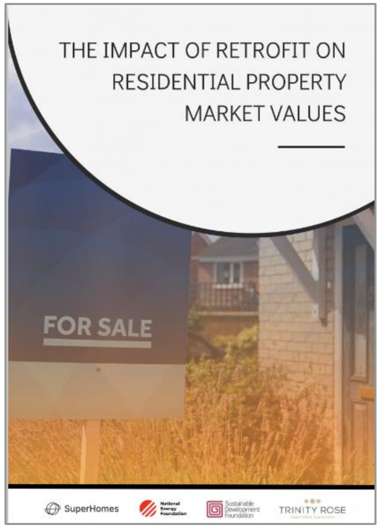


Figure 1.8 - Impact of retrofit on residential property market values (Source: National Energy Foundation)

Funding opportunities and resources

Access to incentives and grants

Funding can come from a variety of sources, including mortgages, loans, cash savings, investment, and grants.

Grant schemes vary over time and have been directed towards a combination of social housing landlords, the public sector, and private homeowners.

Utility companies also offer incentives.

Examples of schemes and grants available to homeowners and landlords are listed to the right.

Scheme/ Grant	Funding	Years of funding in next spending review period
Boiler Upgrade Scheme (BUS)	Up to £7,500 for air source or ground source heat pumps	2025/2026 2027/2028
Heat Pump Investment Accelerator	£15 million	2025/2026
Energy efficiency grant	£400 million	2025/2026 2027/2028
Energy Company Obligation 4	£7000 - £20,000+ for individual applicants	2025/2026
Great British Insulation Scheme	£1 billion, aiming to help 300,000 households	2025/2026
Local Authority Retrofit Scheme	£500 million	2025/2026 2027/2028
Industrial Energy Transformation Fund	£225 million	2025/2026 2027/2028
Public Sector Decarbonisation Scheme	£1170 million	2025/2026 2027/2028
Industrial Energy Efficiency and decarbonisation -	£410 million	2025/2026 2027/2028

Figure 1.9 – List of retrofit grants and schemes available for individuals and business at the time this report was written

Camden's existing building stock

The London Borough of Camden is a dynamic inner London borough with diverse neighbourhoods. The southern part includes iconic institutions like the British Museum and University of London, legal and business hubs in Holborn, and retail centres at Tottenham Court Road. Northern areas such as Camden, Hampstead, and Highgate feature distinctive residential neighbourhoods with unique identities.

Domestic buildings in Camden

According to the Camden climate action plan there over 100,000 homes in Camden, with approximately three quarters of them being flats (a significantly higher proportion than the London or England average). The domestic stock breakdown by dwelling type is shown in Figure 1.10. 47% of the stock is pre-1919, and only 9% is post 2000 according to Consumer Data Research Centre data for Camden in 2015, indicating that a lot of the stock needs to be retrofitted to meet climate change targets.

Non-domestic buildings in Camden

According to the London Building Stock Model (LBSM) based on 2017 data, office buildings make up the majority of the non-domestic buildings in Camden at 44%, followed by retail at 33%. The non-domestic stock breakdown by building type is shown in the pie chart on the right. Camden has the most higher education institutions and student residents in London.

Energy performance of the existing building stock in Camden

The London Building Stock Model (LBSM) is a database providing energy performance data on existing domestic and non-domestic buildings in London. According to the database, the average energy performance of the existing domestic and non-domestic building stock in Camden is equivalent to an EPC rating of D, as illustrated on the adjacent energy efficiency rating map. An EPC rating of D is quite common and indicates average energy efficiency and usually benefit from multiple improvements to enhance their rating.

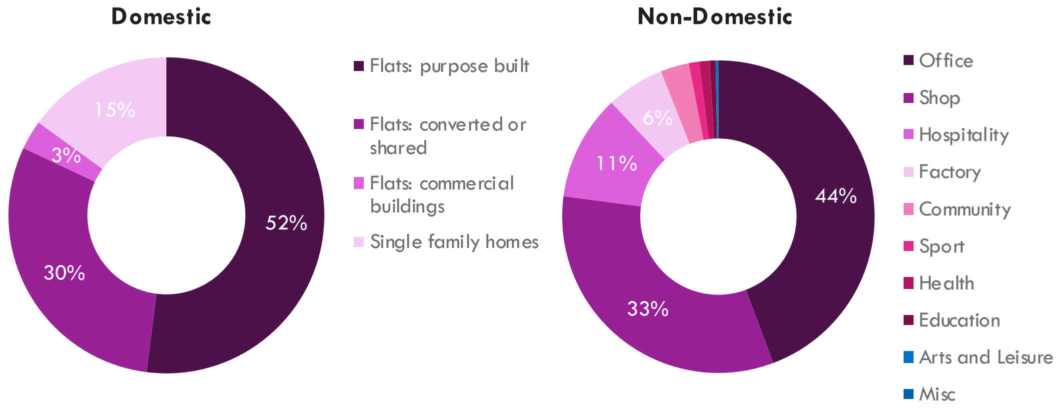


Figure 1.10 - Existing domestic and non-domestic stock break down by building type Source: London Building Stock Model Data for Camden (underlying data from 2017) – LBSM for non-residential buildings and Camden Profile August 2017 for residential buildings

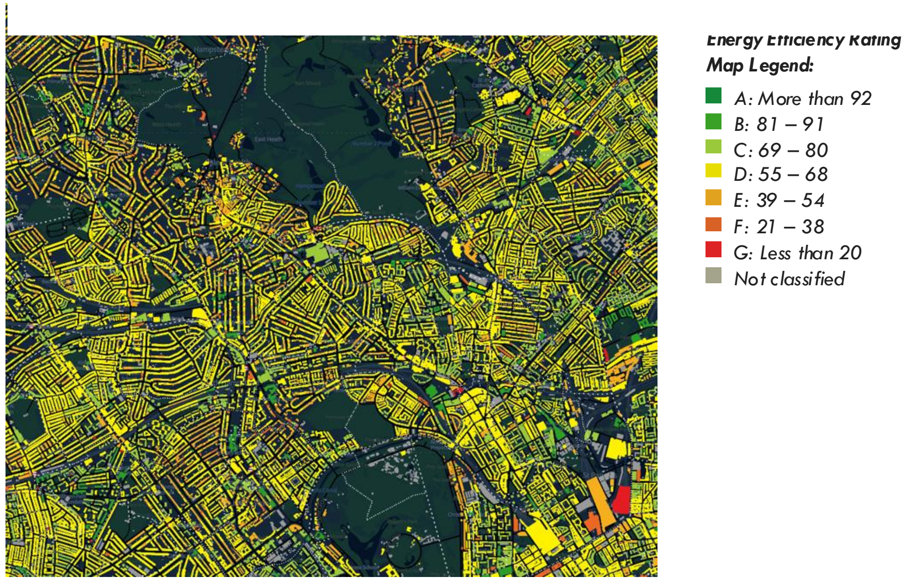


Figure 1.11 - London Building Stock Online Interactive Map illustrating EPC spread across Camden Council and showing that the majority of buildings appear to have an EPC D level of performance which indicates a relatively average energy efficiency. (Source: LBSM)

Summary of the main types of applications in Camden

This page summarises the main types of planning applications in Camden.

Domestic

- Major refurbishment (those requiring planning consent)
- Change of use from non-domestic to domestic
- Internal reconfiguration with addition of residential units
- Extensions (may or may not include alterations)
- Addition of a basement
- Installation of specific measures (e.g. External Wall Insulation, window replacement)
- Alterations to listed buildings

Non-Domestic

- Major refurbishment (those requiring planning consent)
- Façade retention and refurbishment
- Extensions (may or may not include alterations)
- Installation of specific measures (e.g. External Wall Insulation, window replacement)
- Addition of a basement
- Alterations to listed buildings

Summary of the main types of refurbishment work in Camden

Only a relatively small proportion of retrofit and improvement works to existing buildings will be captured by the planning application process and the Local Plan.
This page summarises the different types of applications in Camden which may include retrofit. Works requiring planning permission are shown in **red**, those which generally benefit from permitted development (PD) rights in **orange** (they generally do not require planning permission unless they do not meet the PD rights requirements due to heritage and conservation considerations) and finally those which do not require planning permission in **green**. This depends on whether the proposed works meet the conditions set out in the General Permitted Development Order - this could link to the Planning portal. It is important to note that some permitted development rights may not apply removed by an Article 4 Direction for specific properties and areas or if works are related to a Listed Building.

Planning permission required

Type of application	Building use
Major refurbishment	Domestic
Extensions (may or may not include alterations)	Domestic
Addition of a basement	Domestic
Installation of external measures (e.g. External Wall insulation)	Domestic
Internal reconfiguration with addition of domestic units	Domestic
Major refurbishment	Non-domestic
Change of use (except where there are permitted development rights)	Non-domestic
Extensions (may or may not include alterations)	Non-domestic
Façade retention and refurbishment	Non-domestic
Alterations to listed buildings	Both

These can be impacted by policy

Permitted development rights may apply

Type of application	Building use
Installation of heat pumps	Domestic
Addition of windows, roof lights or skylights	Domestic
Addition of outbuildings	Domestic
Installation of solar PVs	Both
Change of use (specific groups)	Non-domestic

These can potentially be impacted by policy, and can be influenced through guidance and funding

Planning permission not required

Type of application	Building use
Minor refurbishment	Domestic
Installation of internal insulation	Domestic
Loft conversions	Domestic
Repairs, maintenance and minor improvements of external walls	Domestic
Window replacement or improvements (including addition of secondary glazing)	Both
Improvement on lighting and light fittings	Both

These will not be impacted by policy but can be influenced through guidance and funding

2.0

Planning policy context

This section outlines national commitments, building regulations, and the National Planning Policy Framework. It includes a review of regional policies and guidance (e.g. London Plan, GLA Energy guidance, London Net Zero 2030 Pathway) and explores Camden's policy and guidance to encourage low carbon measures, referencing existing retrofit policies and guidance.

Local Authorities have primary duties and powers to mitigate climate change

Primary duties to mitigate climate change

- The **Climate Change Act 2008** sets a clear direction for the UK. It obliges the government to set policy that will enable the UK to achieve Net Zero by 2050 at the latest and to meet its carbon budgets between now and 2050.
- The **National Planning Policy Framework 2023** recognises that the Climate Change Act 2008 duties are relevant to planning for climate change. Paragraph 158 requires that local plans should "*take a proactive approach to mitigating and adapting to climate change*".
- Section 19 of the **Planning and Compulsory Purchase Act 2004** requires that development plan documents must include policies designed to secure that development and use of land "*contribute to mitigation of, and adaptation to, climate change*".

The CCC 2024 progress report: National policy is not enough

In its 2024 Progress Report to Parliament, the Climate Change Committee's assessment was that credible plans cover only a third of the emissions reductions required to achieve the 2030 target and only a quarter of those needed to meet the Sixth Carbon Budget. In particular, the CCC found that missing or incomplete policies include those on energy efficiency in buildings.

Climate Change Act 2008

2008 CHAPTER 27

Department for Levelling Up, Housing & Communities

National Planning Policy Framework

Planning and Compulsory Purchase Act 2004

2004 CHAPTER 5

An Act to make provision relating to spatial development and town and country planning; and the compulsory acquisition of land.

[13th May 2004]

Planning and Energy Act 2008

The 2023 Written Ministerial Statement (WMS) on local energy efficiency standards

The 2023 Written Ministerial Statement

A Written Ministerial Statement (WMS) was made on 13th December 2023 by Baroness Penn, Parliamentary Under Secretary of State for Levelling Up, Housing and Communities and published. A key extract of the statement is:

Any planning policies that propose local energy efficiency standards for buildings that go beyond current, or planned buildings regulation should be rejected at examination ***if they do not have a well-reasoned and robustly costed rationale*** *that ensures:*

- *That development remains viable, and the impact on housing supply and affordability is considered in accordance with the National Planning Policy Framework.*
- *The additional requirement is expressed as a percentage uplift of a dwelling's Target Emissions Rate (TER) calculated using a specified version of the Standard Assessment Procedure (SAP).*

Interpreting the 2023 WMS

Legal opinion is currently divided on whether the 2023 WMS prevents energy-based metrics to be proposed or not. Etude have received legal advice and shared it with Camden Council. It indicated that:

- *The 2023 WMS does not prevent local plan policies based on energy-based metrics from being brought forward by local planning authorities or being found sound in examination.*
- *The 2023 WMS is policy guidance to which regard must be had, but from which deviation can be justified in so long as there is clear evidence which provides the reasons for so doing, and which demonstrates the viability of policies. A robust evidence base is necessary to enable examining inspectors to determine that policies are consistent with national policy and that any deviation from the 2023 WMS is justified.*

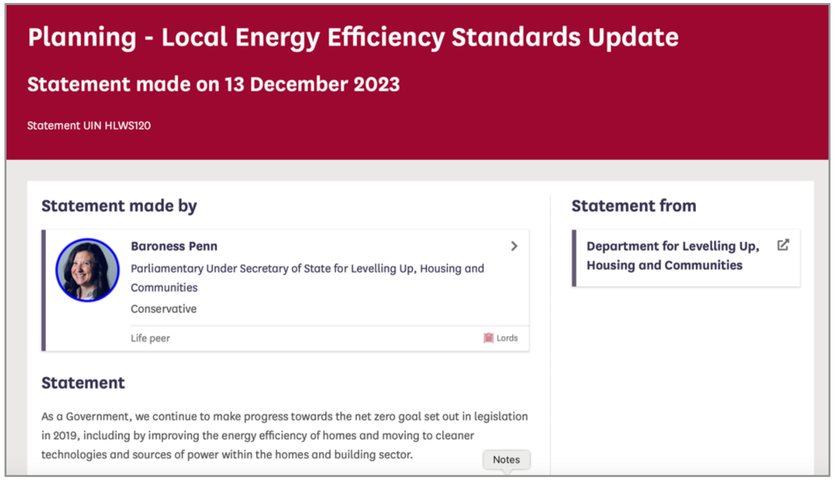
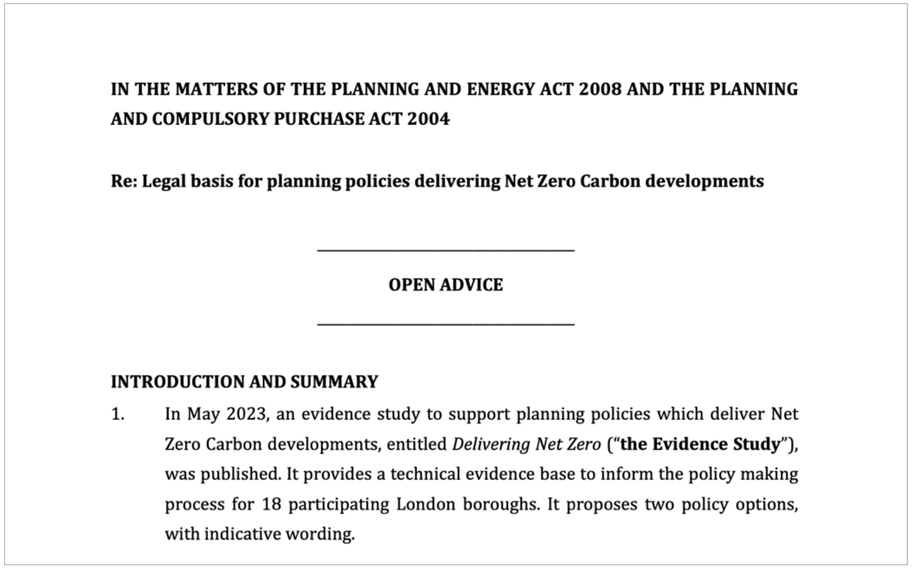


Figure 2.3 - The 2023 Written Ministerial Statement on Planning – Local Energy Efficiency Standards Update can be found at https://questions-statements.parliament.uk/written-statements/detail/2023-12-13/hlws120



IN THE MATTERS OF THE PLANNING AND ENERGY ACT 2008 AND THE PLANNING AND COMPULSORY PURCHASE ACT 2004

Re: Legal basis for planning policies delivering Net Zero Carbon developments

OPEN ADVICE

INTRODUCTION AND SUMMARY

1. In May 2023, an evidence study to support planning policies which deliver Net Zero Carbon developments, entitled *Delivering Net Zero* (“**the Evidence Study**”), was published. It provides a technical evidence base to inform the policy making process for 18 participating London boroughs. It proposes two policy options, with indicative wording.

Figure 2.4 - Written legal advice provided by Estelle Dehon KC to Etude

London Plan 2021 and GLA energy assessment guidance

The London Plan 2021

The London Plan (2021) sets the key requirements for all major developments within the Greater London area. The key policies on energy are Policies SI2, SI3 and SI4.

GLA Energy Assessment Guidance 2022

Major refurbishments

The guidance covers major refurbishments (i.e. those which comprise of 10 or more units and, for non-domestic uses, those with have a floorspace of 1,000m^2 or more). Key extracts include:

- *Applicants are required to generate baseline CO_2 emissions assuming the notional specification for existing buildings, shown in Appendix 4, and which is based on Approved Documents L1 and L2. This will provide a consistent baseline across all refurbishments and clearly distinguish the improvements in CO_2 emissions that are over and above what would ordinarily be undertaken through meeting Building Regulation requirements.*
- *There will be instances where the energy performance of existing elements is more efficient than the Notional Specification for Existing Buildings. [...]*
- *Once the baseline has been established, applicants will be expected to demonstrate that they have incorporated improvement measures that maximise performance at each stage of the energy hierarchy. The BER/DER of the refurbished building should be determined following improvements at each stage of the energy hierarchy using Building Regulations compliance software. These figures should then be used to report the CO_2 savings at each stage of the energy hierarchy in the carbon emissions reporting spreadsheet and included in the energy assessment.*

It is generally acknowledged that the level of carbon savings that can be achieved through a refurbishment can vary considerably, however every effort should be made to improve the energy performance of the building in line with London Plan carbon targets and to follow the energy hierarchy.

Extensions

For developments consisting of a refurbishment with a new build extension, the CO_2 savings for the new and refurbished elements should be presented separately within the energy strategy. The new build elements should be assessed in line with the methodology for new build development and will be expected to comply with London Plan policy.

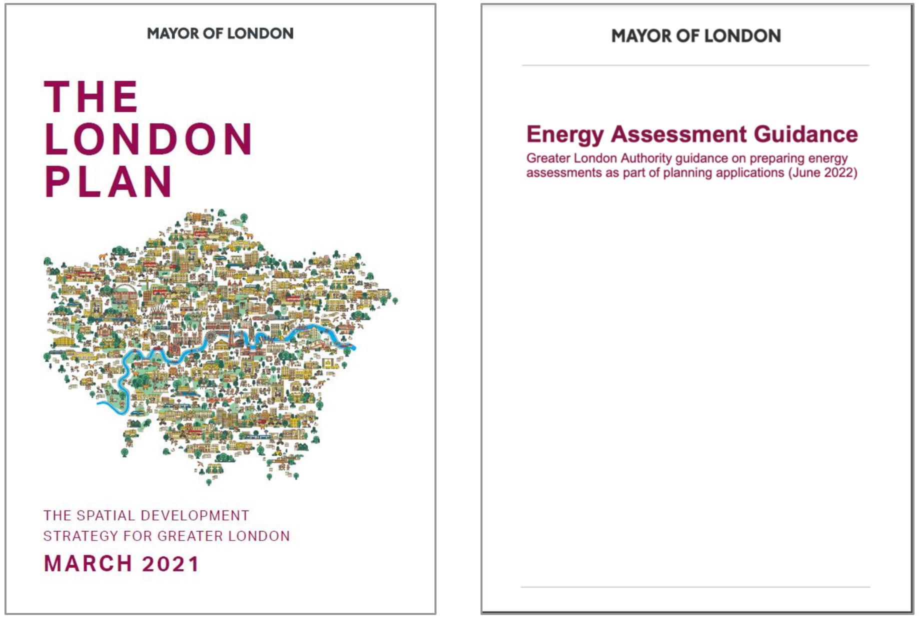


Figure 2.5 - Left: The London Plan 2021; Right: GLA Energy Assessment Guidance, © HM Government

The new London Net Zero 2030 pathway and what it assumes for existing buildings

Achieving Net Zero Carbon by 2030

The London Environment Strategy and the 1.5°C compatible Climate Action Plan, both published in 2018, set out pathways towards Net Zero London by 2050. However, in light of the science which has shown the need for urgent action, the Mayor of London has declared a climate emergency and has brought forward the target for London which now must achieve net zero by 2030.

London Net Zero 2030: an updated pathway

The element energy report '*Analysis of a Net Zero 2030 Target for Greater London*' was published in 2022 and explores four possible pathways that London could take. Based on this analysis, the Mayor of London selected the **Accelerated Green pathway** as the preferred pathway for London to achieve Net Zero. It now replaces the previous trajectory in the 1.5°C Plan.

The new London Net Zero pathway (Accelerated Green)

This pathway aims to reduce baseline carbon emissions (30MtCO_2/yr in 2020) by more than 65% by 2030 down to 10MtCO_2/yr. Key features of this pathway for existing buildings include:

- **40% reduction in space heating demand of buildings.**
- **200,000 homes retrofit each year, to achieve average EPC B or 65kWh/m^2/yr.**
- **Gas boiler replacements banned by 2026.**
- **2.2 million heat pumps by 2030, including additional 215,000 per year in existing homes from 2026**
- **60% of homes supplied with low carbon heat by 2030.**
- **1.5GW of PV generation by 2030 and 3.9GW by 2050.**

This shows the magnitude and scale of retrofit that needs to be undertaken as well as the key retrofit measures which the Local Plan should seek to require and/or encourage.

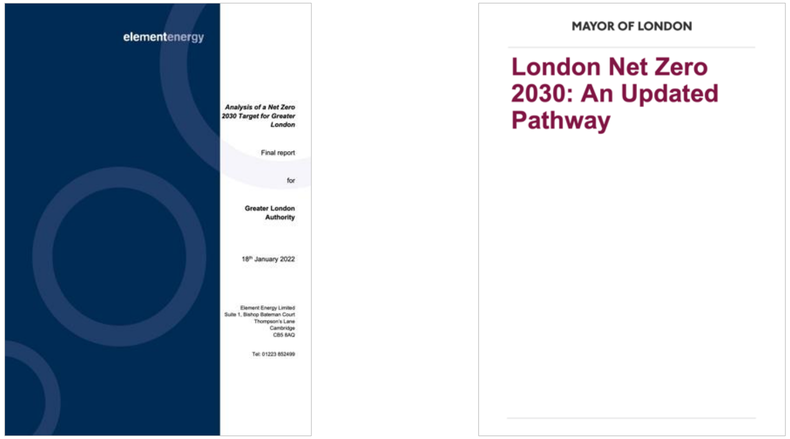


Figure 2.6 - Element Energy report: 'Analysis of a Net Zero 2030 Target for Greater London' (2022) and the GLA's response to the report: 'London Net Zero 2030: An Updated Pathway' (2022)

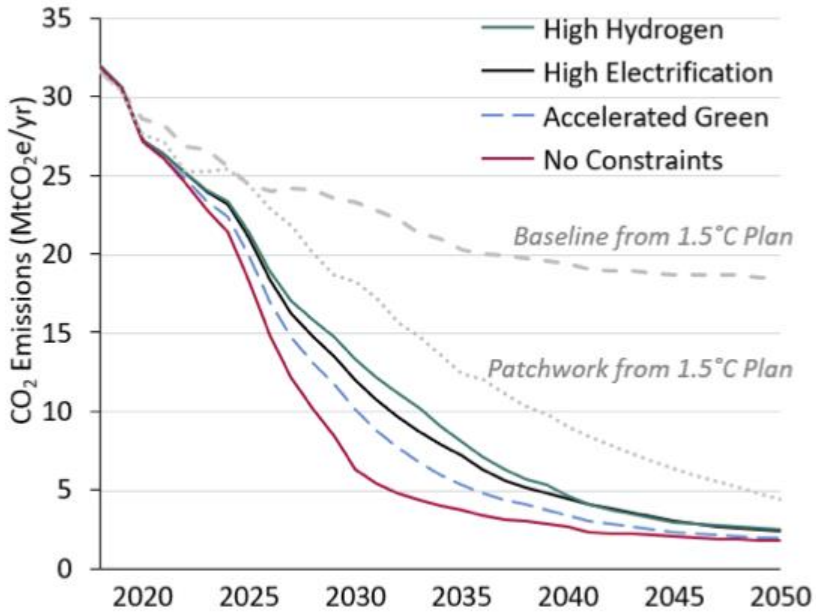


Figure 2.7 - Four pathways were considered by Element Energy and the Mayor of London adopted the 'Accelerated Green' pathway, shown above with a blue dotted line. It shows how decisive action is required over the next 10 years.

Camden Climate Action Plan and Camden Local Plan 2017

Camden's Climate Action Plan

Camden's Climate action plan includes many commitments on existing buildings, including:

- Reviewing the Council's Local Plan Policy on Climate change mitigation, namely the existing zero carbon target and energy efficiency across a range of developments.
- Piloting a fossil-fuel free heating project at a council housing estate.
- Reviewing and extending the Camden Climate Fund to provide financial support for energy efficiency improvement and renewable energy and heat deployment with a focus on the fuel poor and community groups.
- Collaborating with private landlords and housing associations developing a retrofit programme.

Camden Local Plan 2017 and planning guidance

The Local Plan 2017 includes the following policy requirements for existing buildings:

- *Developments of 5 or more homes or 500sqm or more floorspace to achieve a 20% reduction in carbon emissions from renewable energy generation;*
- *Expect non-domestic developments of 500 sqm of floorspace or above to achieve "excellent" in BREEAM assessments.*

Policy CC1 also requires that "*all proposals that involve substantial demolition to demonstrate that it is not possible to retain and improve the existing building*" and expects "*all developments to optimise resource efficiency*".

Camden Planning Guidance (CPG) on 'Energy efficiency and adaptation' provides further detail on the application of CC1.

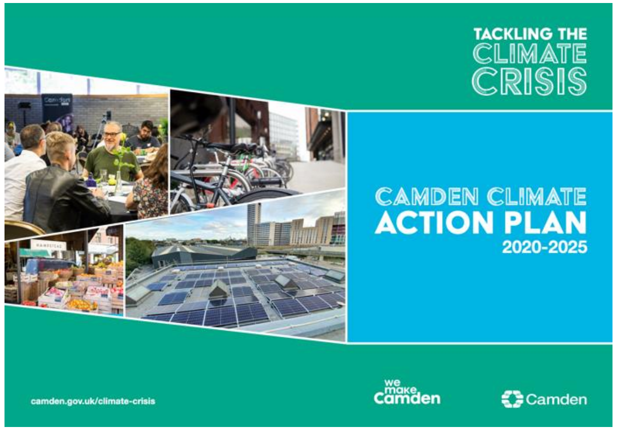


Figure 2.8 - Camden's Climate action plan outlines that Camden's buildings will be energy efficient, comfortable and fit-for-purpose for a zero-carbon future.

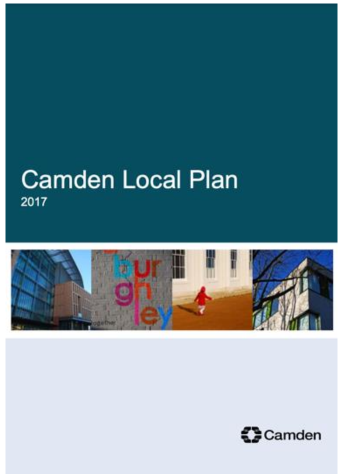


Figure 2.9 - Camden's Local Plan 2017 introduces requirements to reduce carbon emissions when extending the floorspace of existing buildings

Draft New Camden Local Plan 2024

Policy CC5

The policy approach for existing building development in the draft Local Plan has been developed in two parts:

1. To provide a steer to homeowners on interventions to improve the energy performance of their home;
2. To ensure that development which includes the addition of one or more homes in an existing building, or provides a medium to large extension, or replacement of floorspace, includes the following: it reduces the amount of energy needed to heat the building over a year, it uses low carbon heat and it maximises the generation of renewable energy through solar PV as far as practicable.

The targets for space heating demand and Energy Use Intensity (EUI) have been based on the 'LETI Climate Emergency Retrofit Guide'.

Figure 2.10– Draft New Camden Local Plan (2024)

Draft New Camden Local Plan (2024)

Camden Council has published its draft new Local Plan for consultation and engagement (Regulation 18 stage).

Policy CC5 - Energy reduction in existing buildings

A. The Council will support adaptations and improvements to existing buildings to make them more energy efficient and reduce the energy needed to occupy the building. The Council will:

i. Require all development proposals for the alteration, extension and/or conversion of an existing building (including where an element of demolition is proposed) to demonstrate how they have considered and will implement energy efficient improvements. This should be detailed in the Sustainability Statement.

ii. Expect energy efficient improvements to be made appropriate to the scale or nature of the proposal.

iii. Expect energy demand in the part of the building being altered/ extended and/ or converted, to primarily be reduced through improvements to the building fabric. These improvements should comply with the U values set out in Table 6 in the supporting text below.

iv. Require proposals that include the addition or replacement of 500sqm floorspace or more; or developments providing one or more additional dwellings through conversion and / or additional floorspace to:

a. reduce the amount of energy required to heat the building/s over a year, as far as possible, to meet a space heating demand of 50 kwh/m2/ year. Proposals within a conservation area or related to a listed building may be provided an additional allowance of 10 - 20 kWh/m2 where it is demonstrated to the Council's satisfaction that the above target of 50 kwh/ m2/year cannot be met;

b. be fossil fuel-free, and use low carbon heat;

c. demonstrate to the Council's satisfaction that it has maximised the generation of renewable energy on-site (through solar photovoltaics (pv), as far as practical; and

d. Submit an energy statement to demonstrate how the proposal complies with the criteria above.

v. Encourage all other proposals for the alteration, extension and/or conversion of an existing building (not specified in A(iv)) to also meet the standards set out in A(iv) a, b, c and d above.

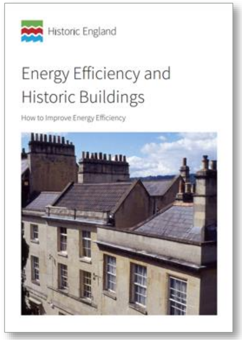
vi. Require proposals that include substantial demolition but retain part of the building to use as little energy as possible and meet an Energy Use Intensity target of 50 kWh/m2/year for residential uses. In instances where minimal existing built fabric is retained (i.e. basement; foundations; a façade; small part of the superstructure) the Council will require the development to meet all energy reduction criteria for new buildings set out in Policy CC6.

Figure 2.11 - Extract of Camden Council's draft Local Plan Policy CC5 on existing buildings

Published guidance on retrofit

London Energy Transformation Initiative (LETI) Climate Emergency Retrofit Guide
Source: LETI (2021)

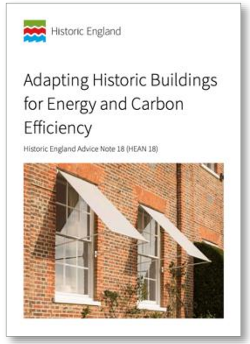
A guide to Retrofitting your home
Source: Trust Mark (2021)



Energy Efficiency and Historic Buildings: How to Improve Energy Efficiency
Source: Historic England (2018)

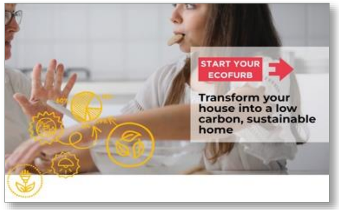
Sustainable Renovation: Improving homes for energy, health and environment
Source: The Pebble Trust (2018)

Retrofit How-To-Guides on retrofitting windows and heat pumps:
Source: Westminster City Council (2022)



Adapting Historic Buildings for energy and Carbon Efficiency
Source: Historic England (2024)

Retrofit Guide for Homeowners (ventilation)
Source: Aereco (2021)



Transform your house into a low carbon sustainable home
Source: EcoFurb (2020)

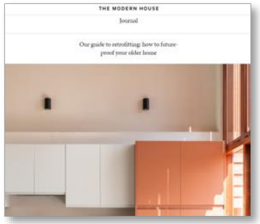
Home for a Low Carbon Future
Source: People Powered Retrofit (2019)

Retrofitting your home
Source: Cambridge City Council (2022)

Other trusted sources for good information and advice about retrofit include:

AECB - Association for Environment Conscious Building
STBA - Sustainable Traditional Buildings Alliance
EH - English Heritage
HES - Historic Environment Scotland
The Green Register
The Retrofit Academy - Retrofit.Support website
UKCMB - the UK Centre for Moisture in Buildings

Whole House Eco-Retrofit
Source: Centre for Alternative Technology (2023)



Our guide to retrofitting: how to future proof your older home
Source: The Modern House (2023)

URBANIST ARCHITECTURE

Retrofitting existing homes: Guide for UK homeowners
Source: Urbanist Architecture (2023)

Retrofit Pattern Book
Source: Greater Manchester Combined Authority, University of Salford and Red

3.0

What factors influence retrofit?

This section highlights various retrofit measures, emphasises the importance of a whole-building retrofit plan, and examines factors influencing retrofit decision-making. It also provides a summary of the main types of retrofit work in Camden and whether planning consent is required.

Summary of key retrofit measures

Retrofit for net zero carbon is the process of upgrading different elements of a building to make it more energy efficient, to move to low carbon heating systems and to enable it to generate renewable energy.

Low carbon heat and no more fossil fuels

The main objective of retrofit should be to accelerate the move away from gas boilers towards heating systems that use electricity (e.g. heat pumps).

Energy efficiency improvements

Energy efficiency improvements save energy, reduce running costs and improve comfort. Upgrading windows, insulating walls, roofs and floors, and retrofitting mechanical ventilation (ideally with heat recovery) all improve energy efficiency.

The combination of measures that are appropriate for a particular building will depend on a variety of factors, including its age, construction, current level of energy efficiency and any technical or heritage constraints.

Solar Photovoltaics (PV)

An increase of solar energy generated in the Borough is needed to reduce carbon emissions and balance energy use. Many homes and commercial buildings have a significant roof space available and can directly benefit from this electricity.

Demand flexibility for a smarter electrical system

Energy storage (e.g. hot water tanks) and smart controls will play an important role in integrating buildings into the wider energy system, helping buildings to use renewable energy when it is produced.

Category	Measure
Energy efficiency	Double or triple-glazed windows
	Insulation (wall, roof, floor)
	Airtightness (wall, roof, floor, junctions)
	Ventilation (e.g. cMEV, MVHR)
Low carbon heat and no more fossil fuels	Individual heat pumps
	Communal heat pumps
	Low carbon heat networks
	Direct electric
Renewable energy generation	Solar PVs
Demand flexibility	Energy storage
	Smart energy controls

Figure 3.1 - Summary of key retrofitting measures

Insulation | Walls

Walls - Insulating externally or internally?

From a heat loss and reduced exposure perspective it is best to externally insulate walls. Allowing the insulation to wrap around the building continuously, keeping it warm and dry, while avoiding the need to address thermal weak points and junctions (e.g. around floor joists) is a significant benefit of external wall insulation. However, the choice will come down to what is practical and visually acceptable.

Cavity wall insulation

It has no visual impact and improves energy efficiency, but not as much as external or internal insulation. It is however generally the first step to adopt. Cavities should be cleaned to the base and filled with a non-hygroscopic, non-capillary active bead insulation to minimise the risk of moisture problems. Existing brickwork should be repointed to keep the wall dry and the rain out of the cavity.

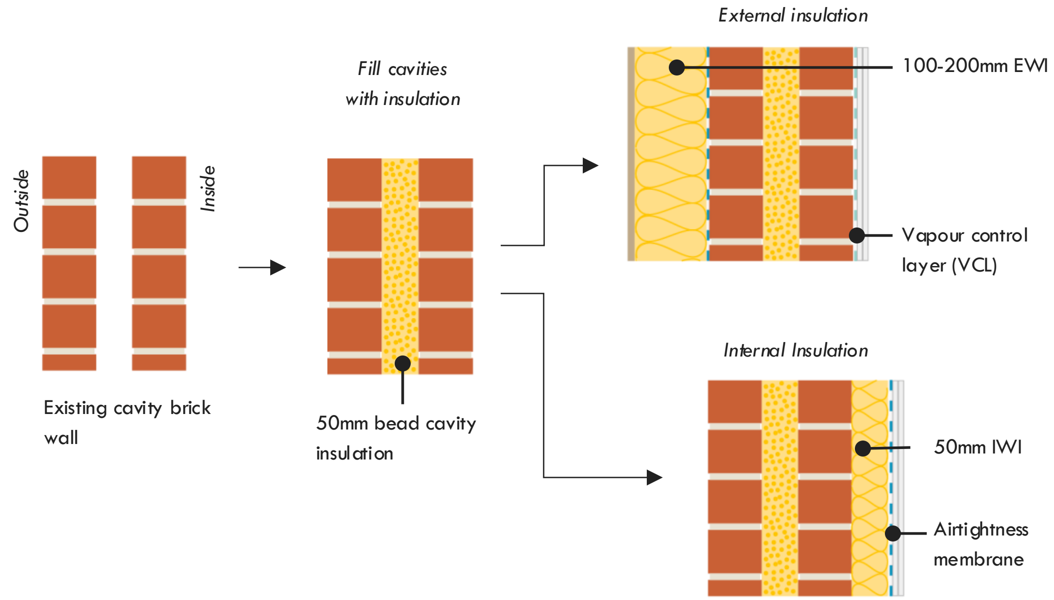


Figure 3.2 - Options for insulating cavity walls. For step 1 ensure measures have been made to prevent condensation.

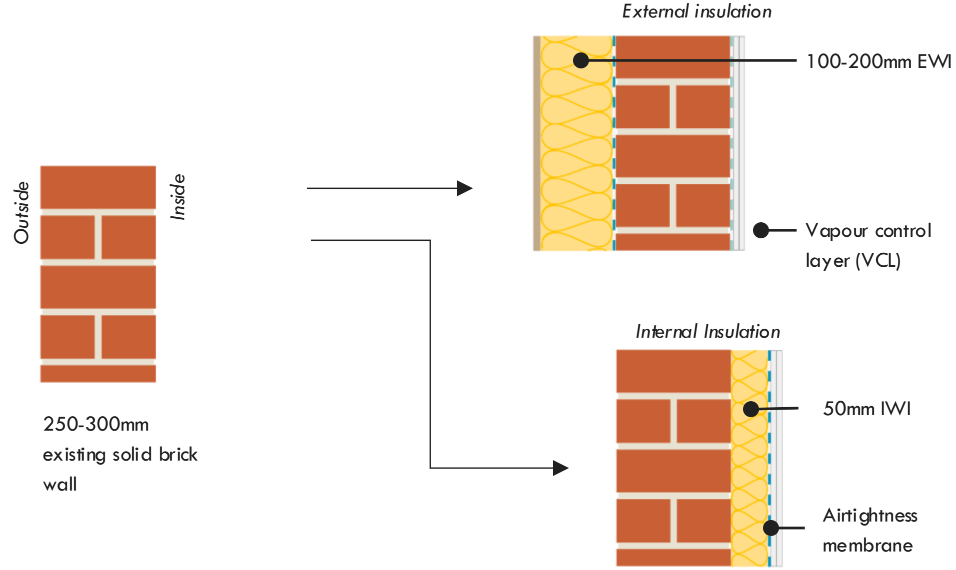


Figure 3.3 - Options for insulating solid brick walls.

Insulation | Loft/roof & ground floor

Loft/roof insulation approach

For unheated attic spaces the simplest approach is to insulate the joists in the loft. It is important to consider the eave-loft junction carefully in order to prevent air leakage and properly ventilate the unheated loft space to avoid the condensation risk.

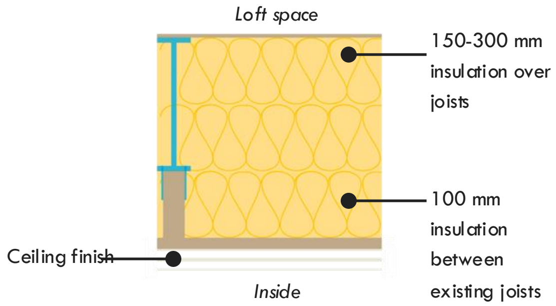
Loft space can also become a ‘warm space’ room by insulating the roof. Insulation can be added in between the rafters and an insulated sheathing board over the rafters as shown in the rafter detail to the right. Attention should be paid to flashing, sealing and roof penetrations such as chimneys, skylights and roof vents, in order to prevent air and water leaks.

Continuous external insulation approach

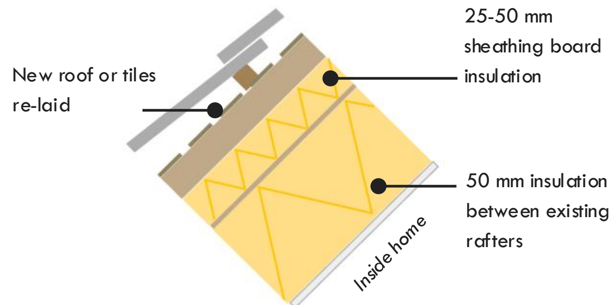
When wall insulation extends up the roof, extending eaves should be considered to cover the additional wall thickness, ensuring a continuous thermal barrier. It is important to maintain or provide ventilation at the eaves and apply flashing and sealing to prevent water ingress. External roof finishes such as tiles and rainwater goods like gutters will need to temporarily move during the installation of external roof insulation.

Ground floor insulation

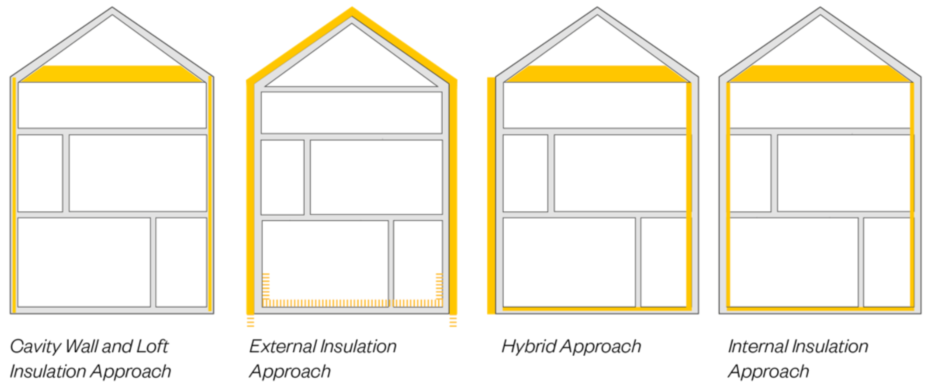
Insulating concrete floors may require raising the floor-level, therefore special consideration should be given on the impact on steps at the entrance, door heights and consistent stairscenarios levels. In the case of raised timber floors, weatherproof insulation can be added between the floor and the ground, protecting the structure from moisture rising from the ground, as well as insulation in between timber joists to enhance the thermal performance of the floor.



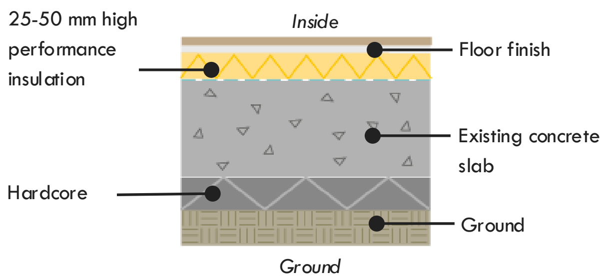
Roof insulation at joist level



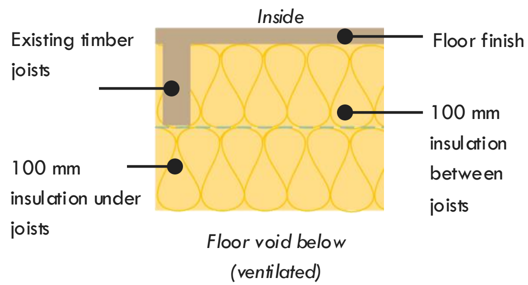
Roof insulation at rafter level



Ensuring continuous insulation



Solid floor



Timber floor

Figure 3.4 - Illustration of different retrofit approaches for insulation to walls, lofts and floors

Insulation

There are many types of insulation products. The following considerations should be made when selecting Insulation:

Area for use - Where the insulation be used (e.g. external wall, roof, floor).

Thermal conductivity - How much heat the material conducts. The lower the conductivity, the better performing the product.

Moisture and air permeability - Some insulation products allow water vapor and/or air to pass through them, and some don't. It is important to understand their hygroscopic properties, particularly when retrofitting older homes to prevent moisture damage to existing structure.

Thickness - The thickness should be considered to ensure it keeps the home warm. For external walls, it is important to ensure that the products used to support insulation are available in the thickness required.

Physical properties - Insulation can be rigid or not, and there are advantages to both.

Fire rating - The building regulations associated with fire rating and insulation should be consulted to ensure safe and compliant products are used in the correct areas.

Compressive strength - Some insulation may require a degree of compressive strength, and this should be considered (usually floors or flat roofs).

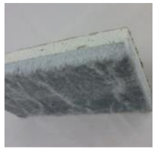
										
Insulation type	**Aerogel**	**Wood fibre board**	**Insulated lime plaster**	**Cork**	**Sheep's wool**	**Hempcrete**	**Mineral wool**	**Glass wool**	**EPS**	**PIR**
Application *EWI = External Wall Insulation IWI = Internal Wall Insulation.*	IWI, roof and ground floor insulation	EWI, IWI	EWI, IWI	EWI, IWI, roof and ground floor insulation	IWI, roof insulation	EWI, IWI, roof and ground floor insulation	EWI, IWI, roof insulation	EWI, IWI, roof insulation	EWI, roof and ground floor insulation	Roof
Key component	Silica	Wood fibres	Lime, cork and clay plaster	Bark of the cork oak tree	Sheep's wool	Hemp mixed with lime-based binder	Mineral fibres	Recycled glass	Rigid plastic foam board Extruded polystyrene	Rigid plastic foam board Polyisocyanurate
Thermal conductivity	0.018-0.015 W/m.K	0.04-0.05 W/m.K	0.045 W/m.K	0.035- 0.043 W/m.K	0.034- 0.042 W/m.K	0.06-0.07 W/m.K	0.034-0.035 W/m.K	0.032-0.037 W/m.K	0.024-0.026 W/m.K	0.021-0.26 W/m.K
Vapour resistance/ breathability	Vapour open and breathable	Vapour open and breathable	Vapour open and breathable	Vapour open and breathable	Vapour open and breathable	Vapour open and breathable	Vapour open and non-breathable	Vapour open and non-breathable	Vapour closed and non-breathable	Vapour closed and non-breathable

Figure 3.5 - Summary of insulation types and their corresponding thermal performance and breathability

Windows and doors

Why are windows so important?

The sheer level of improvement that current glazing technology can now achieve, and the fact that all upgrades can take place with residents staying at home, make this fabric measure very impactful from an energy saving perspective and often the most attractive.

Improving the windows will deliver additional benefits to the occupants such as better thermal comfort (the windowpane will be warmer), less cold draughts and better acoustic insulation.

For many homes and buildings in Camden's conservation areas, an appropriate window upgrade can provide such a significant reduction in space heating demand that it will unlock the ability for a successful replacement of the existing gas boiler by a heat pump. This will enable a a move away from fossil fuel heating and a radical carbon emission reduction of more than 80%.

Window improvements: for a 'Best possible' approach

Altering windows is expensive and likely to only occur once every few decades, especially if embodied carbon is being considered, so it is crucial that changes are made with a view to optimising performance as much as possible. In conservation areas, meeting the statutory requirement to preserve or enhance the character or appearance of the building will also be key.

In all circumstances, a targeted energy performance with a U-value of 1.0 W/m^2.K should be considered. This can be achieved by the following available solutions:

- triple glazing
- best quality evacuated glazing
- advanced secondary glazing.

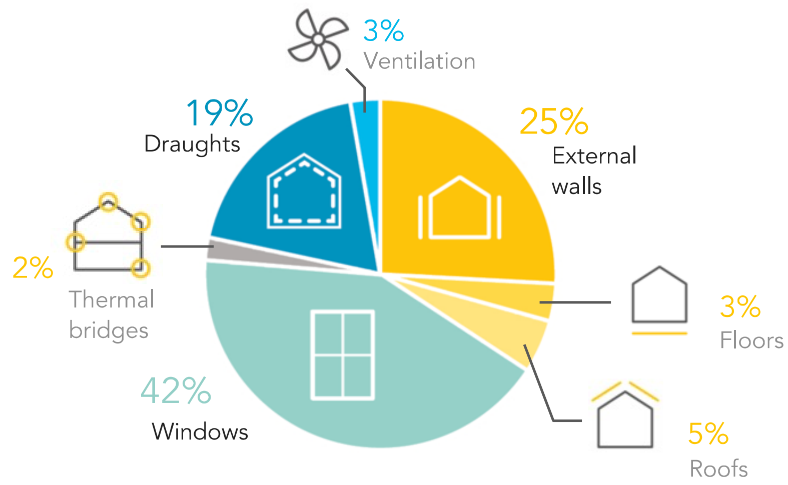


Figure 3.8 - Windows often represent the most significant opportunity to reduce heat losses: example of a Victorian house above (Source: ESSA, Prewett Bizley, Levitt Bernstein, Etude)

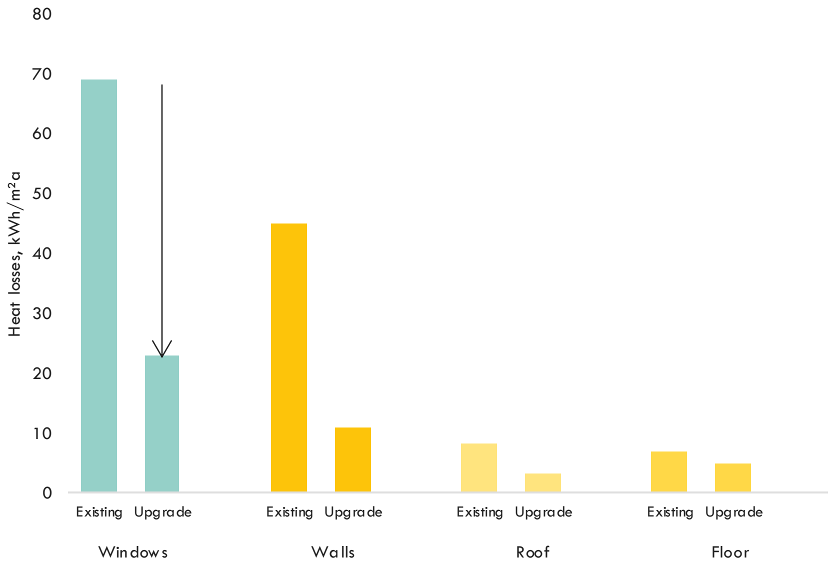


Figure 3.9 - Bar chart showing that for the same house windows are the biggest opportunity for improvement. The amount of improvement for windows is greater per m^2 GIA than any other measure. (Source: ESSA, Prewett Bizley, Levitt Bernstein, Etude)

Airtightness

What is airtightness?

Existing buildings are often draughty which is uncomfortable and increases the amount of heating needed. Making a home more airtight is about eliminating or reducing the level or air leakage in order to retain heat and avoid letting it escape from the house through gaps and cracks, holes, splits and tears in the building envelope (i.e. walls, windows, floors and roof). It is important to note that an airtight dwelling it is not hermetically sealed, it just means that unintended air leakage is reduced to a minimum.

Why should airtightness be considered?

- The most important reason is to avoid losing heat, to reduce energy wastage and costs.
- Making a home airtight also means making it draught free: it improves comfort level.
- An airtight home also reduces external pollutants in the house, reducing the risk of allergies and other respiratory problems.
- Along with a suitable ventilation system, an airtight home will also help to protect the building fabric by reducing damp and the risk of condensation and mould.

How can I make my dwelling airtight?

Any retrofit plans of improvement should include an ambition to improve airtightness: a target should be set, specific improvements identified, and airtightness should be measured at the end of retrofit.

The associated importance of controlled ventilation

The efforts to make your home more airtight must be combined with the introduction of controlled ventilation (see following page).

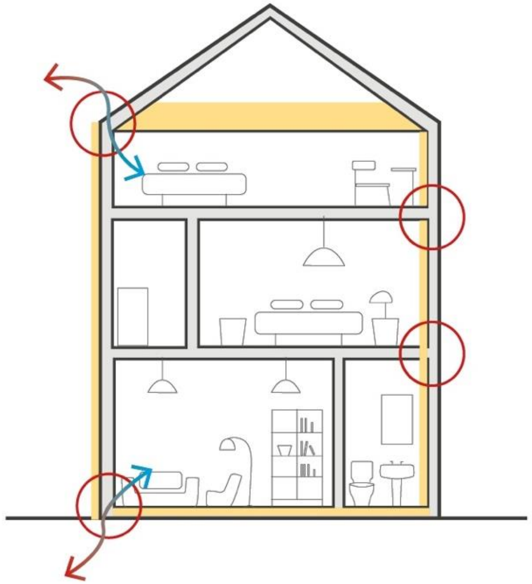


Figure 3.6 - Diagram showing a few examples of potential air leakage points

Figure 3.7 - A range of products are available to improve airtightness: specialist tapes, or specialised grommets that come in a range of sizes.

Ventilation

Sub-standard ventilation is an issue

Most buildings still rely on 'natural ventilation' – opening windows – which is not very effective at making sure all parts of a building have good air movement. This can in turn lead to condensation and even to mould forming in some places, and this risk increases when the building is made more airtight. The retrofit of a system to provide controlled and effective ventilation will help.

What types of ventilation system could be used?

The most energy efficient way to provide controlled ventilation is Mechanical Ventilation with Heat Recovery (MVHR). The equipment circulates air using fans, and transfer heat from the air extracted from the building into fresh air to be supplied.

In retrofit, it is not always possible to find a space for the MVHR unit and/or the associated ductwork to every room. In these scenarios, a compromise option is to use a system of mechanical extract only with trickle vents located on the elevations. Demand controlled mechanical extract ventilation (dcMEV) is a suitable alternative, although it is less efficient than MVHR, so heating demand will be greater.

Installing and commissioning the system

To ensure the system works as planned, the system must be properly tested to ensure it is balanced, delivers the designed fresh air required and does not generate noise beyond what is expected.

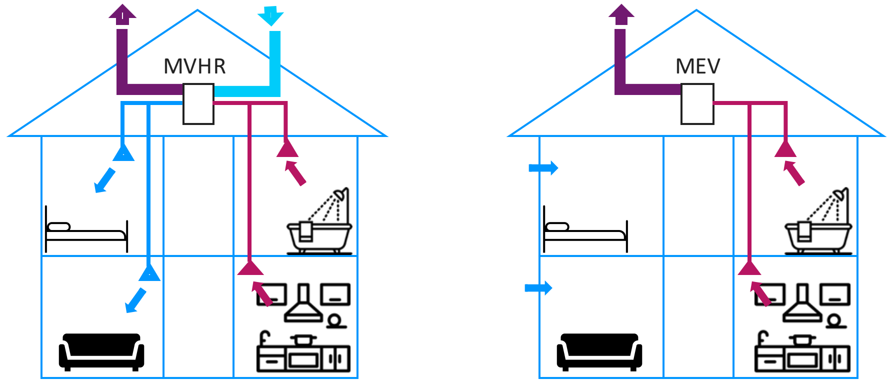


Figure 3.10 - MVHR (left) requires more ductwork than MEV (right) so can be more challenging to fit into retrofit, but MEV is less energy efficient in most homes.

Figure 3.11 - MVHR units can be retrofitted into ceiling voids or wall mounted (© Will South) Ductwork has to be routed to every room. A qualified installer and/or an MVHR manufacturer/supplier will be required to calculate the fresh air required and to design the ventilation system.

Low carbon heat

Electrification of heat

As explained earlier in the report, electricity is the best energy source for low carbon heating. There are two main types of electric heating:

- **Heat pumps** use electricity to take heat from a source (air, water or the ground), increase its temperature, and then move it to where it is needed. Air source heat pumps are the most common form of heat pumps.
- **Direct electric** heating uses electricity to heat radiators, storage heaters or infra-red panels.

Hot water

In some buildings, the energy required for hot water can exceed the amount of energy required for space heating. An energy efficient hot water system is therefore essential to ensure energy use remains low. Well insulated hot water storage is usually the best approach to allow heat pumps to work efficiently, to avoid having very large peaks of electricity demand from the National grid and to allow the storage of energy from PV systems during the day to use later in a cost-effective way.

Low carbon district heat network

District heat networks can be used to provide low carbon heating to existing homes if a suitable centralised low carbon heat source is present. Two types of heat network are expected to be appropriate in communities with urban cities or compact towns, communal ground loop heat pump systems, and deep geothermal networks. There are also hybrid systems combining heat pumps and solar thermal collectors to provide heat to the district network.

Making a logical, low carbon choice

If an existing boiler needs to be replaced, heating alternatives which use electricity should be considered (see adjacent diagram). The specific type of heating to be used should be considered in a logical sequence, starting from the ones which are most efficient.

Figure - 3.12 Front/ Rear garden – ground mounted air source heat pump

Figure 3.13 - Roof mounted air source heat pump

Figure 3.14 - A centralised heat pump system on the roof of a building

Figure 3.15 - Direct electric heating can use wall mounted radiators, panels or underfloor heating

Figure 3.16 - Ground Source Heat Pump gathers heat from the ground via boreholes

Figure 3.17 - Geothermal energy centres gathers heat from deep rock formations

Solar Photovoltaics

Solar PVs can help significantly with carbon emissions and costs

Expanding solar energy in Camden is essential to reducing carbon emissions and creating a more sustainable energy balance. Solar PV systems play a crucial role in reducing electricity import from the national grid. Incorporating solar PV systems into retrofit projects not only contributes to reducing carbon emissions through on-site renewable energy, but it also provides greater control over energy costs and therefore increases their stability over time.

Solar PVs provide substantial long-term savings by generating low-cost electricity after the initial investment, powering appliances, lighting, heat pumps, and EV chargers, which drastically reduces energy bills. With minimal ongoing costs, PV systems enable buildings to lower utility expenses, especially during peak periods. Incentives, rebates and tax credits further offset initial costs.

Recommended steps

- Contact a local MCS certified solar installer to assess the property and provide information on solar panels and inverters. They can also provide a quotation with estimated costs and generation.
- Confirm the roof can take the additional weight loadings and wind forces.
- Install an inverter to convert the electricity generated from direct current (DC) to alternating current (AC). The solar panel installer will usually do this.
- As typically scaffolding will be needed, consider whether this could provide opportunities to carry out other retrofit work such as wall insulation or replacing windows.

Figure 3.18 - PV installation as tile replacement

Figure 3.19 - PV installation over the tiles

Figure 3.20 - PV installation on several roofs

Figure 3.21 - PV installation on building with flats

Figure 3.22 - PV installation over tiles

Figure 3.23 - Concertina PV installation

Sources: www.greenandheritage.uk, www.home-renewables-scotland.co.uk, Historic England, Degee Solar

The retrofit journey and a whole house/building plan

Retrofit should deliver many benefits

The objective of a retrofit project should be to improve the performance, energy efficiency, and sustainability of existing buildings while also enhancing their value, comfort, and longevity.

Phased improvements as part of coherent plan

It may not be possible to implement all retrofit measures at once, but it is important to plan ahead so that packages of work are coherent and complementary. Successful retrofit relies on a a well thought out phasing plan of key measures ensuring that the sequencing of retrofit measures does not impede their implementation in the future.

The preparation of a **whole house/building plan** is recommended to help in that planning. It should be based on a structured process including adequate assessment, design, installation and monitoring.

Standard for Retrofit - PAS 2035

These principles and the concept of whole house/building retrofit planning, as well as and the role of retrofit coordinators have fed into the creation of PAS (Publicly Available Specification) 2035 the UK's first retrofit standard. It helps to deliver quality and manage risks associated with retrofit. PAS 2035 follows two core principles:

1. A **'risk management'** approach to reduce the heat demand of a building as much as possible while ensuring newly airtight homes are well ventilated and avoid issues with damp and humidity.
2. A '**whole house approach to retrofit'** to ensure retrofit plans for homes consider improvements to the fabric, services and renewable energy generation in a coherent way to minimise both risks and carbon emissions.

The whole house/building retrofit plan should:

(a) Set out key building information, constraints, risks, and opportunities related to the building and context (e.g. local air pollution, shading and overheating risk, heritage value).

(b) Set out the key works proposed along with related strategies and details. As a minimum it must cover:

- Repairs/maintenance items that need to be resolved before making changes
- Heating, hot water and ventilation strategy for each phase
- Insulation and airtightness strategy enclosing the building for walls, floors and roofs
- Window and door upgrade strategy
- Critical junctions between upgraded fabric elements that will need to be designed. Set out the sequence of work.

(c) Set out the sequence of multiple phases of works. The strategy should ensure that the design and package of measures for each part integrates with the complete retrofit, avoids obstructing future work phases, and functions in itself without causing issues with the internal conditions or structure of the home.

(d) Include a plan for monitoring and reporting energy consumption.

(e) Stay with the building, recorded in a way that can be handed over to future owners. It should also be a live document, that records works that are undertaken, and may be revised with new proposed strategies.

Figure 3.24 - Whole house/building retrofit plan, adapted from LETI climate emergency retrofit guide

What can be the unintended consequences of retrofit?

Poorly sequencing interventions

Sequencing of measures during a retrofit is critical to ensuring its success. If retrofit measures are poorly sequenced, it can lead to unintended consequences that can undermine the performance, longevity, and have time and cost implications.

Mitigation: Follow a clear and logical sequence and consider integrated design. PAS 2035 provides suitable guidance.

Inadequate ventilation

Improving airtightness is essential for energy efficiency, but it should not be addressed without considering an effective ventilation strategy to prevent moisture issues and mould growth and maintain air quality.

Mitigation: Ensure that ventilation upgrades (such as Mechanical Ventilation with Heat Recovery or continuous mechanical extract ventilation) are installed either before or at the same time as windows and airtightness measures.

Overheating

Fabric improvements can slightly increase the risk of overheating when solar shading and ventilation are not suitably not factored into the retrofit.

Mitigation: Ensure that overheating management strategies (e.g. shading, ventilation) are introduced alongside insulation and airtightness to mitigate overheating risks.

Loss of useable space

The addition of internal insulation can reduce the usable floor area within a building.

Mitigation: Consider external wall insulation where possible or use thinner high-performance insulation materials to minimise space loss i.e. aerogel.

Introduction of thermal bridges

Poor installation of insulation or retrofitting in isolation can result in thermal bridging - areas where heat escapes through junctions or colder parts of the building envelope (e.g. around windows and doors or in corners) - which undermines energy efficiency and can cause condensation and mould issues.

Mitigation: Design and detail insulation carefully to address thermal bridges and pay attention to junctions during the works.

General construction challenges

Poor installation of insulation and air barriers can lead to leaks that compromise the intended benefits of retrofitting. Complex building designs may make it difficult to achieve adequate airtightness without significant effort.

Mitigation: Conduct a detailed survey and condition assessment of the building. Coordinate trades and skills.

Turning a hurdle into an opportunity

Planning policy to support decarbonisation

Planning policy requirements for energy efficiency in new construction have improved over time. However, the same has not happened for works to existing buildings requiring planning consent. The public can see the need for planning permission as a barrier to carrying out the work, but if policy and the process can be used to support those wanting to retrofit buildings well, then there is an opportunity to focus effort and resources on carrying out the most effective changes that also work with the wider community needs.

Environmental and heritage conservation hand in hand

When retrofitting heritage assets, particularly within conservation areas, a sensitive approach is required to balance energy efficiency improvements with the preservation of historical character.

Low carbon retrofit of heritage and traditional construction buildings is possible. Well-planned retrofit programmes can contribute to conservation by incorporating maintenance and repair and offer a new lease of life to buildings. They limit the risk of under-heating, with the associated risks of fabric degradation.

Removing hurdles

The adjacent text box provides some examples of elements which can currently represent a hurdle to a high-quality low carbon retrofit. All development must consider best practice design for the context of the building and area when proposing external alterations. Listed Buildings, developments in Conservation Areas and other heritagewill be assets assessed on a case-by-case basis in discussion with the Council.

Removing unused chimneys which, even when blocked, are a large air leakage path and often a large source of moisture ingress. Chimneys that are not protected or critical to a street scape should be decommissioned and removed wherever possible.

Changes to window frame widths or removing glazing bars is often necessary to accommodate improved window performance, however this is subject to sensitivities in conservation areas. Glazing bars significantly impact window performance.

Ventilation grilles may be needed in external walls to provide supply and extract air and improve air quality.

Space for external wall insulation and roof insulation in the pitch may require an overhang to the street or neighbour, or an increase in ridge height. Providing clear process for applying to highways, party wall surveyors, and even local permitted development for ridge height increases would make rolling out retrofit easier in many situations. This would need consultation with heritage officers.

Figure 3.25 - Elements that can represent a hurdle to a high-quality low carbon retrofit

Retrofit guidance for historic and listed buildings

Successful heritage management is achieved by respecting and understanding historic significance whilst accepting the need for change and improvement.

The National Planning Policy Framework [NPPF] introduced a presumption in favour of sustainable development whereby proposed developments which correctly balance the requirements of economic, social and environmental issues should be granted planning permission unless there are strong reasons why permission should not be granted.

The **Historic England's Climate Change and Historic Building Adaptation advice note** (2023) sets out to support consistent decision making on energy efficiency interventions. It states that conservation of the heritage asset should always be given great weight, but it also provides guidance suggesting what might be an acceptable loss.

The **Historic England's Adapting Historic Buildings for Energy and Carbon Efficiency advice note** (2024) provides clarity - in support of consistent decision making - on approaches to improve the energy efficiency and support carbon reduction of historic buildings, whilst conserving their significance. In particular Section 4 provides advice on the acceptability of changes to historic buildings in response to climate change, as managed through the planning process. It covers draught proofing, windows, insulation, heating systems and heat pumps and solar panels. It is designed for all types of listed buildings and unlisted buildings in conservation areas.

Draft Text for consultation - National Planning Policy Framework - DLUCH

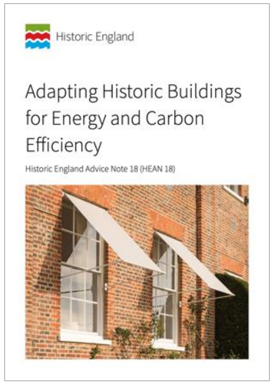
NPPF - Draft Text for consultation paragraph 163

"Local planning authorities should also give significant weight to the need to support energy efficiency and low carbon heating improvements to existing buildings, both domestic and non-domestic (including through installation of heat pumps and solar panels where these do not already benefit from permitted development rights). Where the proposals would affect conservation areas, listed buildings or other relevant designated heritage assets, local planning authorities should also apply the policies set out in chapter 16 of this Framework."

Climate Change and Historic Building Adaptation- Historic England

Climate Change and Historic Building Adaptation - Advice note

"When applications for changes to a building in response to climate change are assessed, a balance will have to be made between the significance of the heritage asset and the public benefits (that is positive climate action) provided by the proposal."



Historic England Advice Note 18

Adapting Historic Buildings for Energy and Carbon Efficiency - Advice note

"Our historic buildings must continue to change and evolve if they are to both contribute to a greener future and be fit for purpose for the people who live in, experience and care for them. If done thoughtfully and carefully, these changes can achieve the complementary goals of protecting our heritage and adapting to a changing climate. Historic England has produced this Advice Note to provide clarity on key considerations and to support consistent decision making.."

Good practice retrofit in London and the rest of the UK

Current initiatives from London boroughs

Virtually all London boroughs are developing good and best practice retrofit initiatives. These include demonstrator projects (houses, blocks of flats, schools), specific work on heat decarbonisation, renewable energy generation, demand flexibility, as well as more strategic initiatives on delivery, cost assessment and funding, stock assessment and modelling.

Existing research and guidance published by the GLA

A number of resources are available, including the GLA reports on heat pump retrofit in London (2020) and on Building Renovation Passports (2021).. In addition, the Retrofit Accelerator programme aims to help London boroughs and partners develop energy efficiency projects at scale with technical and commercial solutions

National initiatives

- **Policy proposals** including measures for commercial property and the private rented sector (requiring minimum EPC rating by 2030) and for mortgage lenders (requiring disclosure and possibly minimum EPC ratings for the stock they lend to).
- **The Construction Leadership Council's draft National Retrofit Strategy** placing local leadership and delivery partnerships at its heart.
- **Funding initiatives**, including the Social Housing Decarbonisation Fund (SHDF) and the energy efficiency local supply chain demonstration projects (BEIS).

Other relevant local initiatives and guidance

- Nottingham Deep Retrofit Energy Model
- Greater Manchester Combined Authority: People Powered Retrofit with Urbed & Carbon Coop
- UKGBC Accelerator Cities Programme, including the Retrofit Playbook.

Demonstrator projects

- **Houses:** Brent, Enfield, Lewisham, Newham, Richmond , Sutton, Wandsworth, Waltham Forest
- **Blocks of flats:** City of London, Enfield, Greenwich, Hackney, Haringey, Kensington & Chelsea, Redbridge, Richmond & Wandsworth, Sutton

Delivery, skills, supply chain

- **Skills:** Camden's stakeholder engagement event
- **Energiesprong:** Enfield, Haringey, Sutton
- **Window manufacturing:** Newham
- **Parity Projects' Ecofurb**

Figure 3.26 - Above are examples of current initiatives on demonstrator projects and initiatives in the area of delivery, skills and supply chain by London Boroughs (as of April 2021)

Examples of good practice retrofit

The examples on this page demonstrate that retrofit has taken place successfully across a wide number of types of homes and tenures.

Key

Properties with External Wall Insulation

Balfron Tower, Tower Hamlets

Grove Road, Hounslow Homes

Edward Woods, Hammersmith and Fulham

Adams Row (Listed) Grosvenor, RBKC

Artic Street, Housing Coop Camden

Ernley Close, One Manchester

Great Arthur House, City of London

Wilmcote House, Plymouth City Council

Channel Islands Estate, Enfield

Princedale Rd, Octavia Housing, RBKC

Culford Rd, Hackney

Akerman Rd, Lambeth Homes

Bloomsbury house (listed), Camden

4.0

Methodology

This section details the building typologies modelled as part of this evidence base, and summarises scenarios, energy modelling outputs, and benchmarks for evaluating retrofit outcomes.

Benchmarks, targets and limits

Existing retrofit benchmarks, limits and targets

There are various benchmarks, targets and limits related to the energy performance of retrofit. AECB, the Passivhaus Institute and LETI have all developed space heating and energy use limits for homes as well as elemental targets.

The Net Zero Carbon Buildings Standard

Various organisations including BBP, BRE, the Carbon Trust, CIBSE, IStructE, LETI, RIBA, RICS, and UKGBC have come together to develop a UK wide Net Zero Carbon Buildings Standard ('the Standard'). The pilot version launched in September 2024.

It provides a rule book to robustly prove that built assets are net zero carbon and in line with the UK's climate targets. It is aligned with the UK's remaining carbon budget and provides clarity on how to assess new and existing buildings to determine whether they are Net Zero Carbon aligned.

The Net Zero Carbon buildings standard is an 'in-use' standard, based on measured data. In the future, projects will be able to verify that a building conforms to the Standard. Projects will undergo an initial verification, and then subsequently re-verification providing further data proving that they still conform with the standard.

There are various technical requirements of the Standard shown to the right. In addition to the mandatory aspects of the standard that require meeting targets, limits and reporting requirements, projects can choose to offset their carbon emissions.

It is expected that a pilot testing scheme to gather feedback on the process of implementing the standard will be launched at the end of 2024.

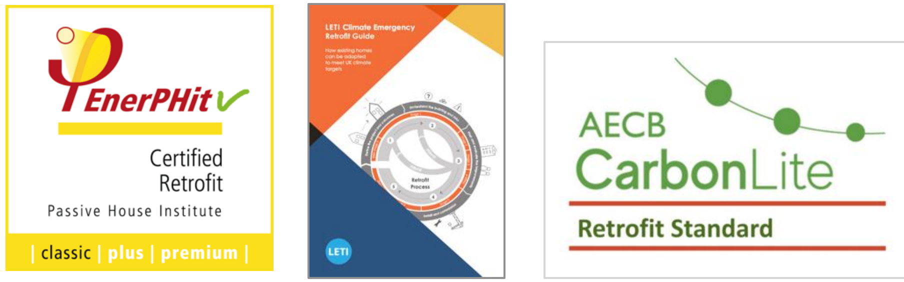


Figure 4.1 - Available industry guidance on targets and limit for retrofit

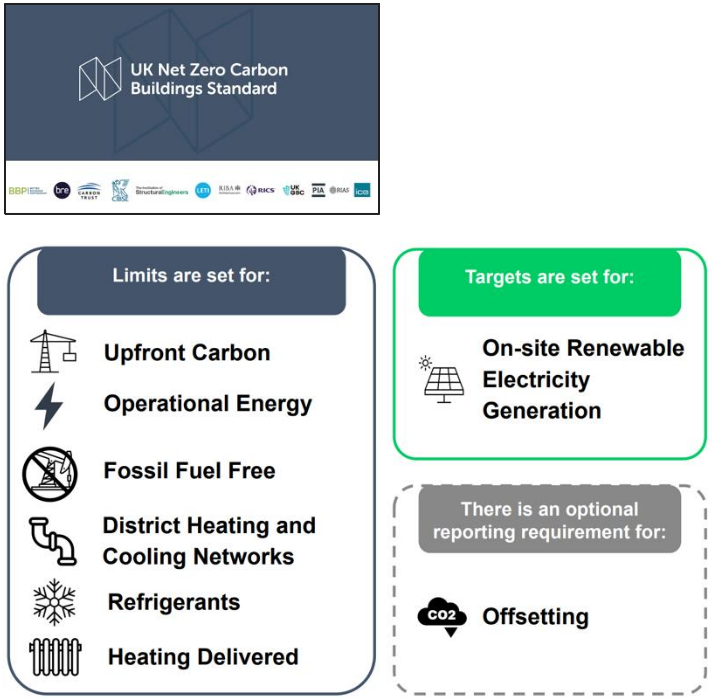


Figure 4.2 - Technical requirements of the UK Net Zero Carbon Buildings Standard. The pilot version of the UK Net Zero Carbon Buildings Standard will be launched in Sept 2024

NZCBS requirements for domestic buildings

The requirements can differ depending on building type, if a building is new or existing and when works commence. The limits and targets for existing single-family homes where the retrofit commences onsite in 2025 are shown to the right.

Energy use limits for existing buildings

- Energy use intensity (EUI) limits for 'comprehensive whole-building retrofit' projects remains the same each year and depends on the year the retrofit starts. For a retrofit commencing in 2025 the limit is 75 kWh/m^2.yr, in 2030 it will be 70 kWh/m^2.yr and in 2040 it will be 58 kWh/m^2.yr.
- For 'stepped retrofits,' homes must meet an EUI limit below the 'stepped retrofit curve'. In 2025 the energy use limit of a single-family homes is 95 kWh/m^2.yr this reduces every year until 2040 where the EUI limit remains at 58 kWh/m^2.yr until 2050. To comply annually, staged retrofits must follow this curve and have a retrofit plan.

Space heating limit

There are limits on annual space heating delivered to new homes, but not for existing homes.

Refrigerant GWP limit

The GWP limit for the refrigerant in buildings is 677kgCO_2e/kg.

On-site renewable requirement

The on-site renewable electricity generation target depends on the region that the building is located. For existing buildings, there are exemptions including: planning constraints, overshadowed roofs, access, structural capacity, existing plant areas and existing rooflights.

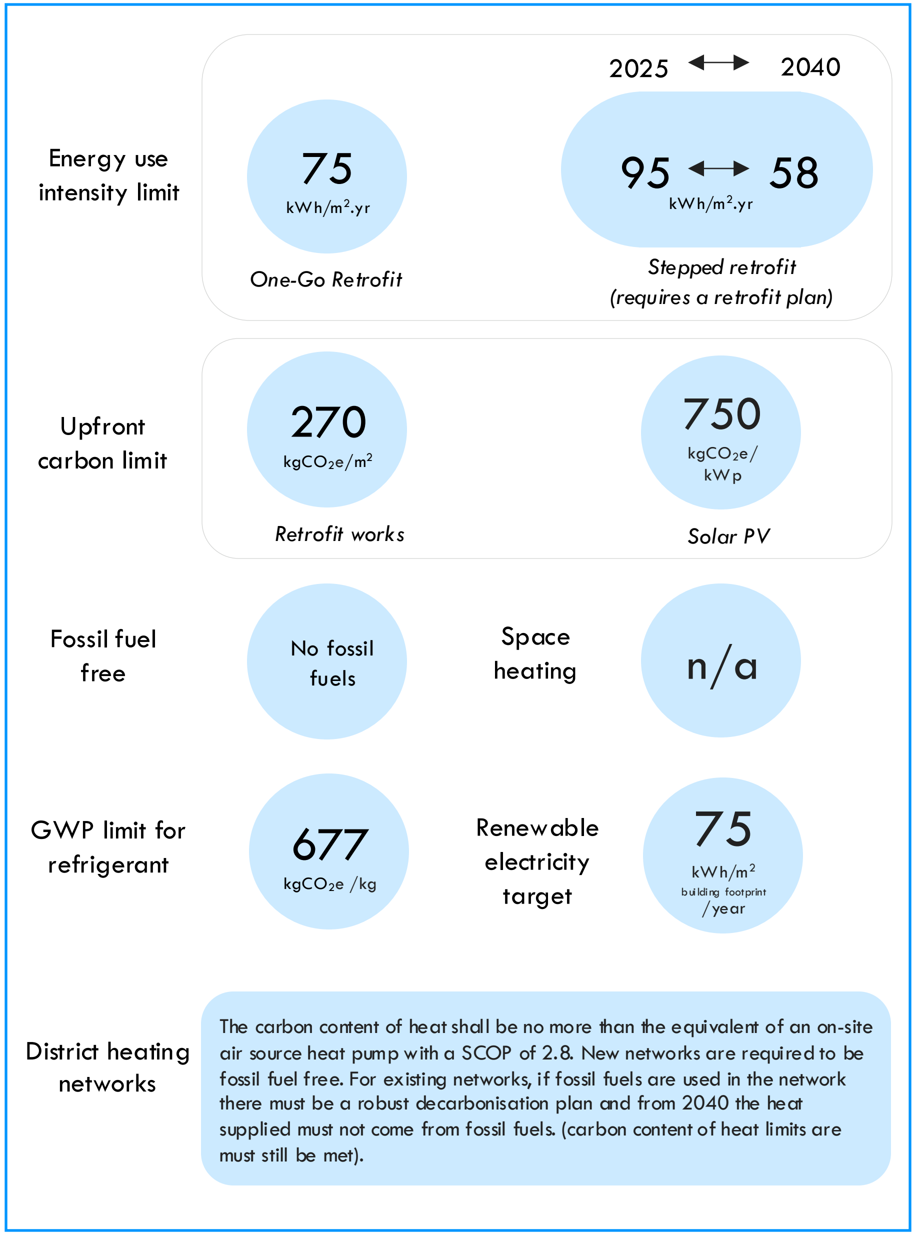


Figure 4.3 - Net Zero Carbon Buildings standard requirements - Existing buildings - single family homes in Camden – assuming that the retrofit commences in 2025

Net Zero Carbon Buildings Standard | Limits and targets for non-domestic buildings (offices)

NZCBS requirements for non-domestic buildings

The limits and targets to the right are for existing offices assuming that the retrofit commences onsite in 2025.

Energy use limit for existing buildings

- Energy use intensity (EUI) limits for a specific 'comprehensive whole-building retrofit' projects remain the same year each and is based on when the retrofit starts. For a retrofit that commences in 2025, the limit is 100 kWh/m^2.yr, in 2030 it will be 85 kWh/m^2.yr, and in 2040 it will be 55 kWh/m^2.yr.
- For 'stepped retrofits', the office has to meet an EUI limit that is lower than the 'stepped retrofit curve'. In 2025 the energy use limit of an office is 120 kWh/m^2.yr dropping each year until it stabilises at 55 kWh/m^2.yr by 2040 until 2050. To comply annually, staged retrofits must follow this curve and have a retrofit plan.

Space heating limit

There are no limits on annual space heating delivered to new or existing offices, but these might come in in future versions of the Standard.

Refrigerant GWP limit

The GWP limit for the refrigerant in buildings is 677kgCO_2e/kg.

On-site renewables

The on-site renewable electricity generation target depends on the region that the building is located. For existing buildings, there are exemptions including: Planning constraints, overshadowed roofs, access, structural capacity, existing plant areas and existing rooflights.

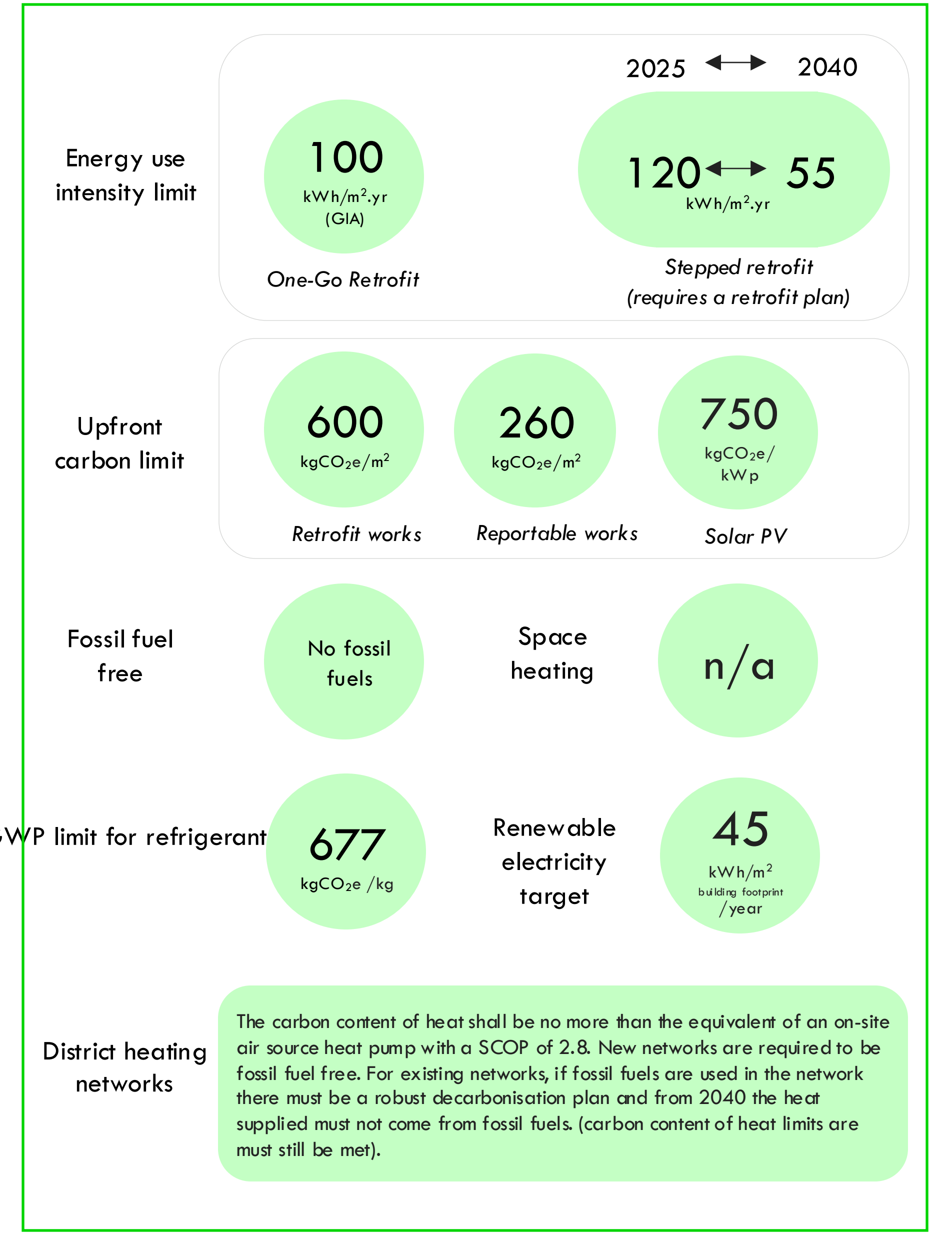


Figure 4.4 - Net Zero Carbon Buildings standard requirements - Existing offices in Camden – assuming that the retrofit commences in 2025

The Table on the right is taken from the LETI Climate Emergency Retrofit Guide.

It lists target u-values and other specification values for constrained retrofit (in the case of listed buildings for example) and unconstrained retrofit (where there are few technical or heritage limitations). Exemplar values are also suggested.

https://www.leti.uk/retrofit

SIGNPOST Chapter 4 - LETI home retrofit targets - 4.3 Constituent element method

Building element		Retrofit actions	LETI best practice: Constrained retrofit	LETI best practice: Unconstrained retrofit (cool temperate climate)	LETI exemplar: All retrofit types
Walls	Cavity	External, cavity or Internal insulation	0.24 W/m².K	0.18 W/m².K	0.15 W/m².K
	Solid uninsulated	External or Internal insulation	0.32 W/m².K	0.18 W/m².K	0.15 W/m².K
	Timber frame	External or Internal insulation	0.21 W/m².K	0.18 W/m².K	0.15 W/m².K
Roofs	Cold	Insulate	0.12 W/m².K	0.12 W/m².K	0.12 W/m².K
	Warm/flat	Insulate	0.22 W/m².K	0.12 W/m².K	0.12 W/m².K
Floors	Suspended timber	Insulate between joists	0.20 W/m².K	0.18 W/m².K	0.15 W/m².K
	Solid uninsulated	Excavate and insulate below	0.80 W/m².K	0.15 W/m².K	0.15 W/m².K
Windows and doors	Windows	Replace	1.30 W/m².K	1.00 W/m².K	0.80 W/m².K
	Doors	Replace	1.00 W/m².K	0.80 W/m².K	0.80 W/m².K
General envelope	Thermal bridging	Mitigate where possible	0.10 W/m.K	0.10 W/m.K	0.08 W/m.K
	Airtightness	Draught proofing, sealing of chimneys and vents	3.0 ach@50Pa	2.0 ach@50Pa	1.0 ach@50Pa
Systems	Systems and appliances	Fossil fuel free home	Fossil fuel free	Fossil fuel free	Fossil fuel free
	Ventilation type	Install and remove extract fans	MVHR*	MVHR	MVHR
	Lighting power	Replace lamps and fittings	50 lm/W	100 lm/W	100 lm/W
Hot water	Hot water tank	Increase insulation or replace	1.5 W/K	1.5 W/K	1.5 W/K
	Primary pipework	Insulate all pipework	90% of pipework insulated	90% of pipework insulated	90% of pipework insulated
	Shower demands	Low flow fittings	16 litres/pers.day	16 litres/pers.day	16 litres/pers.day
	Other demands	Low flow fittings	9 litres/pers.day	9 litres/pers.day	9 litres/pers.day
Renewables	Photovoltaic generation	Rooftop installation	0 % of roof area covered in PV panels	40 % of roof area covered in PV panels	40 % of roof area covered in PV panels

* If not possible use demand control dMEV or demand control cMEV

Introduction to the methodology used for this technical evidence base

Modelling representation of prominent Camden typologies

The energy and cost modelling that form the basis of this evidence base was conducted on two representative typologies that capture key building types in Camden.

The first typology, a mid-terrace house from the late 19th to early 20th century, reflects Camden's residential sector, where 47% of homes were built before 1919, according to data from the Consumer Data Research Centre. Since much of Camden's housing stock is older, refurbishment applications involving alterations, conversions, or additional floorspace will likely be concentrated on these properties.

The second typology, a 1960s large office building, was chosen due to the prominence of office spaces in Camden, where 44% of non-domestic buildings are offices, according to the London Building Stock Model (LBSM).

These typologies were modelled to determine the effect and the cost of specific improvements to the existing building fabric in conjunction with extension or conversion refurbishment works.

Figure 4.6 – Example of a typical 1880-1900 Terrace House in Camden

Fabric specifications for new extensions

For both typologies, the initial improved specifications against building regulations for the new extensions modelled were sourced from the LETI climate emergency design guide which are outlined in Table 6 from the Draft Local Plan 2024.

Residential Fabric U-values (W/m2 .K)	Non-residential Fabric U-values (W/m2 .K)
Walls 0.13 - 0.15 Floor 0.08 - 0.10 Roof 0.10 - 0.12 Exposed ceilings/floors 0.13 - 0.18 Windows 0.80 – 1.0 (triple glazing) Doors 1.00 Include openable windows, cross ventilation, and include external shading	Walls 0.12 - 0.15 Floor 0.10 - 0.12 Roof 0.10 - 0.12 Windows 1.0 (triple glazing) - 1.2 (double glazing) Doors 1.2

Figure 4.5 - Table 6: Building material fabric U-value specifications from Camden's Draft Local Plan 2024

Figure 4.7 – Example of a typical 1960s Large Office Building in Camden

Before presenting the extensive results of this analysis, this section summarises our general approach to energy and cost modelling, providing a coherent framework for understanding the impacts and benefits of our suggested interventions.

Terrace house baseline

To model the energy performance of a terraced house, we established a baseline case to serve as a reference point for assessing the impact of various retrofit measures. This baseline represents a typical late 19th century terraced property in Camden, characterised by common construction features that contribute to poor energy efficiency. The 3-storey, 185 sqm house does not have any extensions.

- **Building fabric:** the house is assumed to have a building envelope consisting of a suspended timber floor without insulation, solid brickwork external walls lacking cavity or internal insulation, and a pitched roof with minimal insulation.
- **Ventilation:** the ventilation strategy is based on natural ventilation, relying on air infiltration and manual window operation.
- **Heating and hot water:** we modelled a standard gas combi boiler system, reflecting the predominant heating solution in many homes in Camden.
- **Solar PVs:** they have not been included in the baseline but as a retrofit measure.

The above assumptions have enabled us to simulate the energy performance of the house before improvements, enabling a clear comparison with subsequent retrofit scenarios and quantifying the potential gains in energy efficiency and carbon reduction from each intervention. Different modelling specifications were modelled and are described in Table 1.

Baseline case

185 sqm; 3-storeys

This building represents the generic Terrace House typology

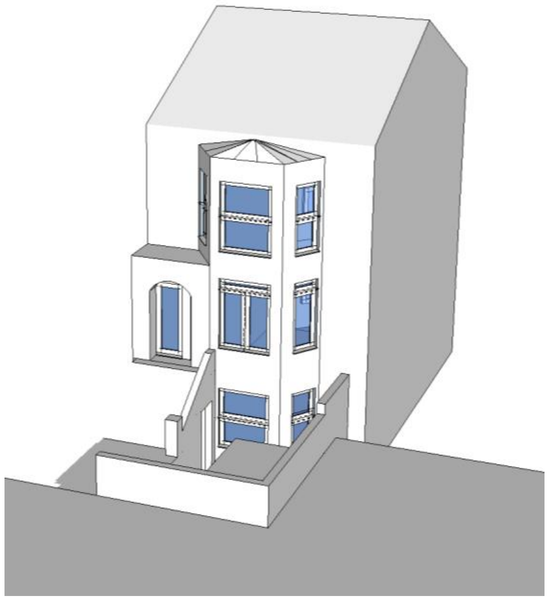


Figure 4.7 – Example of a typical late 19th century Terrace house in Camden

Option 1	Option 2.1	Option 2.2	Option 2.3	Option 3.1	Option 3.2	Option 4	Option 5
Existing Building without extension	*Loft Insulation replacement*	*External wall Insulation replacement*	*Floor Insulation replacement*	*Double glazed Windows & Ventilation replacement*	*Triple glazed Windows & Ventilation replacement*	*Heat Pump installation*	*Whole house retrofit*
No Insulation	Insulation	Insulation	Insulation	No Insulation	No Insulation	No Insulation	Insulation
Single glazed	Single glazed	Single glazed	Single glazed	Double glazed	Triple glazed	Single glazed	Triple glazed
0% Extract fan only	0% Extract fan only	0% Extract fan only	0% Extract fan only	> HR 80% Mechanical Ventilation with Heat Recovery	> HR 80% Mechanical Ventilation with Heat Recovery	0% Extract fan only	> HR 80% Mechanical Ventilation with Heat Recovery
Gas Boiler - 80% efficient	Gas Boiler - 80% efficient	Gas Boiler - 80% efficient	Gas Boiler - 80% efficient	Gas Boiler - 80% efficient	Gas Boiler - 80% efficient	Air-to-water Heat Pump – COP 4.0	Air-to-water Heat Pump – COP 4.0
No Solar PVs	No Solar PVs	No Solar PVs	No Solar PVs	No Solar PVs	No Solar PVs	No Solar PVs	

Table 1 - Example of the different levels of fabric and ventilation efficiency considered. The full list of assumptions for each typology can be found in Appendix A. Greyed icons indicate measures which have not been included in each option case.

Selection of the extension for modelling

To conduct the energy and cost modelling for this technical evidence base, a selection of domestic extensions were identified and assessed.

Given the diverse range of building extensions in the borough and the considerable variation within each building type, we have focused on three prominent extension types for residential houses: upward, outward, and basement extensions.

These types of extensions were determined through discussions with Camden Council and analysis of recent planning applications in Camden. A summary description of each extension type is provided with the adjacent images.

While the chosen examples have inherent limitations (e.g. the outward extension is one-storey high, not two), it is standard practice for technical evidence bases to rely on specific examples which are considered fairly representative and common.

Different scenarios/combinations of specifications have been modelled

We modelled different scenarios by combining various specifications related to building fabric, ventilation, heating systems, and solar PVs. These scenarios range from specific fabric upgrades with mechanical ventilation to incorporating low carbon heating solutions and solar PV. The results enable Camden Council to understand the likely impact of these combinations of measures.

Predictive energy modelling outputs

The different extended houses and the associated performance specifications were modelled using a predictive operational energy modelling tool: Passive House Planning Package (PHPP) Version 10.4. The key outputs of the calculations were the estimate of the space heating demand (SHD) and Energy Use Intensity (EUI) for each case and each building.

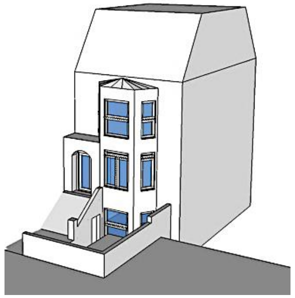
Domestic extensions modelled

Baseline case

185 sqm

3-storeys

This model represents the generic terrace house typology

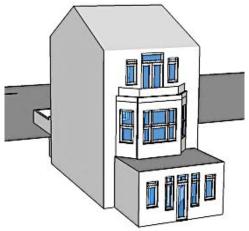


Upward extension

235 sqm

4-storeys

This model represents a typical loft extensions to the terrace house typology

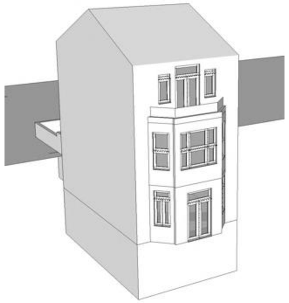


Outward rear extension

200 sqm

3-storeys

This model represents a typical rear ground floor extension to the terrace house typology



Basement extension

245 sqm

4-storeys

This model represents a typical new habitable basement extension to the terrace house typology

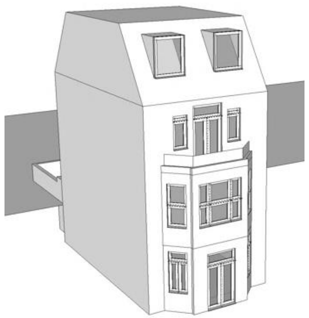
Figure 4.8 – Graphical representation of a baseline model of the existing terrace building and three subsequent extensions to the house which have been modelled

A set of specifications which considered various levels of performance for building fabric, ventilation, heating systems and renewable energy provision were modelled. The performance of these scenarios range from ‘business as usual’ approaches (option 1) to more ambitious ‘ultra-low energy’ approaches (options 5 - 7). Each of the six modelling specifications are the same for all extension scenarios and they are described as follows:

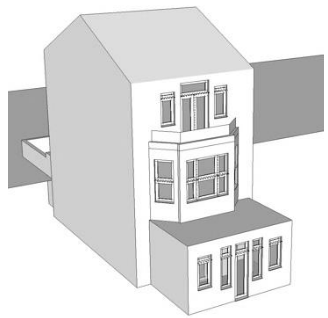
- **Option 1** – Existing terraced house with a new extension modelled using fabric efficiency based on minimum building regulations requirements, natural ventilation and gas boiler (no PVs).
- **Option 2** – Existing terrace house remains unchanged and there is a slight improvement to the fabric efficiency for the new extension based on the fabric specifications outlined in Figure 4.5 on page 48.
- **Option 3 –** Same fabric specifications as Option 2 with a change of heating system to direct electric for the new extension only.
- **Option 4** – Existing terrace house remains unchanged with ultra-low energy fabric improvements to the new extension only.
- **Option 5** – Existing terrace house remains unchanged with ultra-low energy fabric improvements, a Mechanical Ventilation with Heat Recovery (MVHR) and an upgraded heating system solution - air-to-air heat pumps to the new extension only, as well as solar PVs.
- **Option 6** – The fabric specification for both the existing terrace house and new extension are the same as Option 5 but an air-to water heat pump replaces the gas boiler for the whole house
- **Option 7** – Fabric improvements are made to the existing terrace house as well. A MVHR is also installed for the whole house. An air-to water heat pump replaces the gas boiler for the whole house

	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6		Option 7	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*Low energy fabric + Direct electric (extension only)*		*Ultra low energy fabric (extension only)*		*Ultra-low energy fabric, MVHR and heat pump (extension only)*		*05 + heat pump (whole house)*		*Whole house retrofit*	
	Existing Building	Extension	Existing Building	Extension	Existing Building	Extension	Existing Building	Extension	Existing Building	Extension	Existing Building	Extension	Existing Building	Extension
Floor (W/m²K)	1.00	0.18	1.00	0.10	1.00	0.10	1.00	0.08	1.00	0.08	1.00	0.08	0.25	0.08
Walls (W/m²K)	2.10	0.18	2.10	0.15	2.10	0.15	2.10	0.13	2.10	0.13	2.10	0.13	0.30	0.13
Walls with ground effect(W/m²K)	2.10	0.18	2.10	0.18	2.10	0.18	2.10	0.15	2.10	0.15	0.30	0.15	0.30	0.15
Dormer Walls (W/m²K)	N/A	0.30	N/A	0.30	N/A	0.30	N/A	0.13	N/A	0.13	N/A	0.13	N/A	0.13
Dormer Roof (W/m²K)	N/A	0.25	N/A	0.25	N/A	0.25	N/A	0.12	N/A	0.12	N/A	0.12	N/A	0.12
Roof (W/m²K)	0.45	0.15	0.45	0.12	0.45	0.12	0.45	0.12	0.45	0.12	0.50	0.12	0.50	0.12
Windows (W/m²K)	5	1.4	5	1.0	5	1.0	5	0.80	5	0.80	5	0.80	0.80	0.80
	(single-glazed)	(double glazing)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(triple-glazed)	(triple-glazed)
Rooflights (W/m2K)	3	2.2	3	1.2	3	1.2	3	1.2	3	1.2	2.2	1.2	1.2	1.2
Doors (W/m²K)	2.5	1.4	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	1.0	1.0
Thermal bridge allowance	3	5	3	4	3	4	3	4	3	4	3	4	3	4
Air Permeability (ACH)	8	5	8	5	8	5	8	5	8	<3	5	<3	< 3	< 1
Ventilation	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	80% HR. 2m duct 25mm insulation	Natural ventilation with intermittent extract fans	80% HR. 2m duct 25 mm insulation	80% HR. 2m duct 25 mm insulation	80% HR. 2m duct 25 mm insulation
	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.40 ACH	0.2 to 0.5ach	0.40 ACH	0.40 ACH	0.40 ACH
	SFP - 0.15 W/m3/h	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	SFP - 0.45 Wh/m3	0.15 Wh/m3	SFP - 0.45 Wh/m3	SFP - 0.45 Wh/m3	SFP - 0.45 Wh/m3
Space Heating	Gas combi boiler	(same as house)	Gas combi boiler	(same as house)	Gas combi boiler	Direct Electric	Gas combi boiler	(same as house	Gas combi boiler	Air-to-Air Heat Pump	ASHP	(same as house)	ASHP	(same as house)
	Radiators > 60˚C	(same as house)	Radiators > 60˚C	(same as house)	Radiators > 60˚C	Electric heaters	Radiators > 60˚C	(same as house	Radiators > 60˚C	Cassette unit	Radiators < 35˚C	(same as house)	Radiators < 35˚C	(same as house)
	-	(same as house)	-	(same as house)	-	(same as house)	-	(same as house	-	2.6kW (9000btu)	8kW	(same as house)	5kW	(same as house)
	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house	Efficiency - 80%	COP - 3.5 to 4.0	COP - 3.5 to 4.0	(same as house)	COP - 3.5 to 4.0	(same as house)
	Weather comp - No	(same as house)	Weather comp - No	(same as house)	Weather comp - No	(same as house)	Weather comp - No	(same as house	Weather comp - No	Weather comp - Yes	Weather comp - Yes	(same as house)	Weather comp - Yes	(same as house)
Domestic Hot Water	None	(same as house)	None	None	None	None	None	(same as house)	None	(same as house)	Hot water storage cylinder, 120mm insulation at 60˚C	(same as house)	Hot water storage cylinder, 120mm insulation at 60˚C	(same as house)
	10mm pipe insulation poor	(same as house)	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	(same as house)	10mm pipe insulation poor	20mm pipe insulation medium	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good
	None	(same as house)	None	None	None	(same as house)	None	(same as house)	None	(same as house)	180L	(same as house)	180L	(same as house)
Technology*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Monocrystalline silicon	N/A	Monocrystalline silicon	N/A	Monocrystalline silicon
PV installed peak kWp*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	N/A	3	N/A	3
System loss %*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10 - 20%	N/A	10 - 20%	N/A	10 - 20%

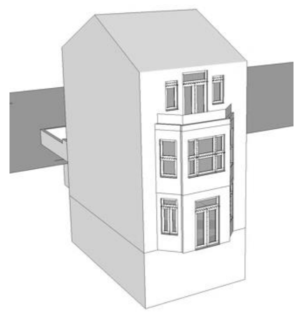
Table 2 - Example of the seven different levels of fabric and ventilation efficiency considered. Although the same ‘levels’ are considered for each typology, the detailed fabric and ventilation specifications for each of these levels are specific to each typology. ***The full-sized list of assumptions for each typology can be found in Appendix A.***



Upward extension



Outward rear extension



Basement extension

Methodology | Terrace house | Single family home to flats

The change of use scenario assumes an upward and outward extension are incorporated for the conversion of the Terrace house to flats. In contrast to the modelling undertaken for the extensions, low carbon heating is introduced from Option 3, with solar PV installations included in Options 3 through 6. The modelling specifications are as follows:

- **Option 1** – Existing terrace house modelled using fabric efficiency based on minimum building regulations requirements, natural ventilation and gas boiler (no PVs).
- **Option 2** – Existing terrace house remains unchanged and there is a slight improvement to the fabric efficiency for the new extension based on the fabric specifications outlined in Figure 4.5 on page 48.
- **Option 3 –** Same fabric specifications as Option 2 with a change of heating system to direct electric in all flats.
- **Option 4** – Same fabric specifications as Option 2 with a change of heating system to air-to-air heat pumps and an MVHR in all flats, as well as PVs on the roof.
- **Option 5** – ultra low fabric for the extension only, with MVHR and the introduction of air-to water heat pumps to the whole house.
- **Option 6** – Fabric improvements and additional MVHR to the existing house resulting in a whole house retrofit and PVs.

	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*02 + Direct electric (extension only) & PV*		*Low energy fabric, MVHR (extension only) and heat pump (whole house)*		*04 + Ultra-low energy fabric (extension only)*		*Whole house retrofit*	
	Existing Building	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**
Walls (W/m²K)	2.10	0.18	2.10	**0.15**	2.10	0.15	2.10	0.15	2.10	**0.13**	**0.30**	0.13
Dormer Walls (W/m²K)	N/A	0.30	N/A	**0.30**	N/A	0.30	N/A	0.30	N/A	**0.13**	**0.16**	0.13
Dormer Roof (W/m²K)	N/A	0.25	N/A	**0.25**	N/A	0.25	N/A	0.25	N/A	**0.12**	**0.16**	0.12
Roof (W/m²K)	0.45	0.15	0.45	**0.12**	0.45	0.12	0.45	0.12	0.5	**0.12**	**0.16**	0.12
Windows (W/m²K)	5	1.4	5	**1.0**	5	1.0	5	1.0	5	**0.80**	**0.80**	0.80
	(single-glazed)	(double glazing)	(single-glazed)	**(triple-glazed)**	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	**(triple-glazed)**	(triple-glazed)
Rooflights (W/m2K)	3	2.2	3	**1.2**	3	1.2	3	1.2	2.2	1.2	1.2	1.2
Doors (W/m²K)	2.5	1.4	2.5	**1.0**	2.5	1.0	2.5	1.0	2.5	1.0	**1.0**	1.0
Thermal bridge allowance	3	5	3	**4**	3	4	3	4	3	4	3	4
Air Permeability (ACH)	8	5	8	5	8	5	8	5	5	**<3**	**< 3**	**< 1**
Ventilation	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	**80% HR. 2m duct 25mm insulation**	Natural ventilation with intermittent extract fans	80% HR. 2m duct 25 mm insulation	**80% HR. 2m duct 25 mm insulation**	**(same as house)**
	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	**0.40 ACH**	0.2 to 0.5ach	0.40 ACH	**0.40 ACH**	**(same as house)**
	SFP - 0.15 W/m3/h	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	**SFP - 0.45 Wh/m3**	0.15 Wh/m3	SFP - 0.45 Wh/m3	**SFP - 0.45 Wh/m3**	**(same as house)**
Space Heating	Gas combi boiler	(same as house)	Gas combi boiler	(same as house)	**Direct Electric**	(same as house)	**ASHP**	(same as house)	ASHP	(same as house)	ASHP	(same as house)
	Radiators > 60°C	(same as house)	Radiators > 60°C	(same as house)	**Electric heaters**	(same as house)	**Radiators < 35°C**	(same as house)	Radiators < 35°C	(same as house)	Radiators < 35°C	(same as house)
	-	(same as house)	-	(same as house)	-	-	**8kW**	(same as house)	8kW	(same as house)	**5kW**	**(same as house)**
	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house)	-	-	**COP - 3.5 to 4.0**	(same as house)	COP - 3.5 to 4.0	(same as house)	COP - 3.5 to 4.0	(same as house)
	Weather comp - No	(same as house)	Weather comp - No	(same as house)	Weather comp - No	(same as house)	**Weather comp - Yes**	(same as house)	Weather comp - Yes	(same as house)	Weather comp - Yes	(same as house)
Domestic Hot Water	None	(same as house)	None	None	None	(same as house)	**Hot water storage cylinder, 120mm insulation at 60°C**	(same as house)	Hot water storage cylinder, 120mm insulation at 60°C	(same as house)	Hot water storage cylinder, 120mm insulation at 60°C	(same as house)
	10mm pipe insulation poor	(same as house)	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	(same as house)	**25mm pipe insulation good**	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good
	None	(same as house)	None	None	None	(same as house)	**180L**	(same as house)	180L	(same as house)	180L	(same as house)
Technology	N/A	N/A	N/A	N/A	N/A	**Monocrystalline silicon**	N/A	Monocrystalline silicon	N/A	Monocrystalline silicon	N/A	Monocrystalline silicon
PV installed peak kWp	N/A	N/A	N/A	N/A	N/A	**3**	N/A	3	N/A	3	N/A	3
System loss %	N/A	N/A	N/A	N/A	N/A	**10 - 20%**	N/A	10 - 20%	N/A	10 - 20%	N/A	10 - 20%

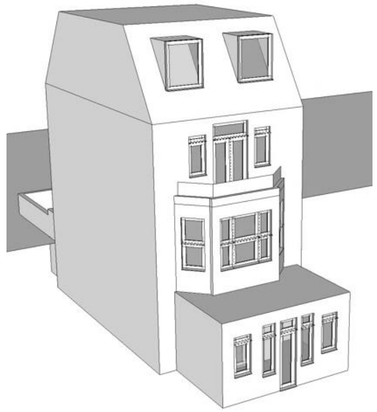
Table 3 - Example of the six different levels of fabric and ventilation efficiency considered. Although the same 'levels' are considered for each typology, the detailed fabric and ventilation specifications for each of these levels are specific to each typology. ***The full-sized list of assumptions for each typology can be found in Appendix A.3.***

Terrace to flats

250 sqm

4-storeys

This building represents the generic terrace to flats conversion



Methodology | Office | Baseline

Office building baseline

To model the energy performance of the existing office block and different extension and retrofit scenarios, we established a baseline case to serve as a reference point for assessing the impact of various retrofit measures.

This baseline represents a typical 1960s office block in Camden. The 7-storey, 5,192 sqm office block is assumed to have an existing (approximately) 20-year-old side extension of 5 storeys. It is characterised by common construction features that contribute to poor energy efficiency, such as little insulation and single glazed windows.

- **Building fabric:** the baseline building envelope consists of a concrete floor without insulation, solid, uninsulated brickwork external walls, a concrete flat roof without insulation and single glazed windows. The side extension is assumed to be built to a minimum Part L 2002 specification.
- **Ventilation:** the office is assumed to be ventilated by mechanical ventilation supply and extract without heat recovery.
- **Space heating and hot water:** we modelled an older non-condensing gas boiler system, reflecting the predominant heating solution in most old UK office blocks.
- **Solar PVs:** they have not been included in the baseline but as a retrofit measure.

This configuration allows us to simulate and estimate the energy consumption of the office block before improvements, enabling a clear comparison with subsequent retrofit scenarios and quantifying the potential gains in energy efficiency and carbon reduction from each intervention. The modelling specifications unique to the baseline case are described in Table 4.

Existing Building without extension	*Existing extension*
No Insulation	Some insulation
Single glazed	Double glazed
0% Supply and extract fan only	0% Supply and extract fan only
Gas Boiler	Gas Boiler
No PVs	No PVs

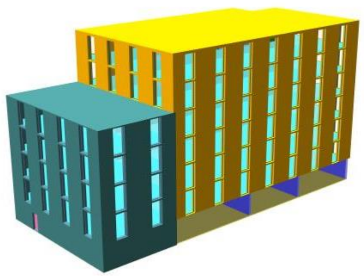
Table 4 – Specifications assumed for the baseline case of the office block. The full list of assumptions can be found in Appendix A.4.

Baseline case

5,192 sqm

7-storeys main building and 5-storeys side extension

This building represents a generic office block typology



Overview of extension scenarios

The draft Local Plan policy CC5 requires developments that include an additional, or replacement of ≥500m^2 floorspace to reduce the amount of energy required to heat the building, be fossil fuel free, use low carbon heat, and maximise the generation of renewable energy through solar photovoltaic panels.

Given the diverse range of office building extensions in Camden and the considerable variation within each building type, we have focused on one prominent extension type for office buildings, the upward extension. This was decided through discussions with Camden Council and analysis of recent planning applications in Camden. Specifications for the baseline and the extension scenarios have been summarised on Tables 5 and 6.

While the chosen example has inherent limitations (e.g. the outward extension is two-storey high, not three or four), it is standard practice for technical evidence bases to rely on specific examples which are considered fairly representative and common.

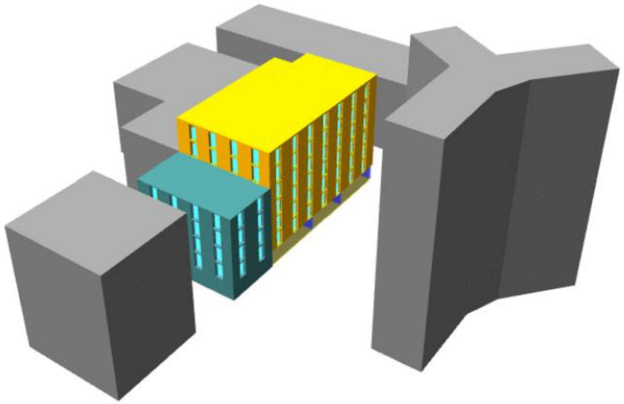
Six different scenarios/combinations of specifications

We modelled six different scenarios by combining various specifications related to fabric and ventilation, heating systems, and solar PVs for the upward extension. Details of the scenarios can be found in Appendix A.4.

Predictive energy modelling outputs

The buildings were modelled using EDSL TAS Version 9.5.6 software in accordance with the CIBSE TM54 guidance and methodology for evaluating operational energy use. It is important to note that a key principle of this methodology is that the predicted consumption should be taken as a range, which accounts for a level of uncertainty in the operation and management of the building.

Office building - scenarios modelled

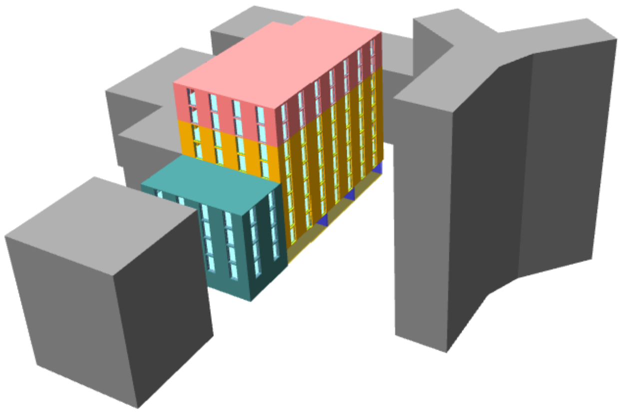


Baseline case (indicated in yellow) with existing extension (indicated in blue)

5,192 sqm

7-storeys main building and 5-storeys back extension

This building represents a generic office block typology



Upward extension (indicated in pink)

6,387 sqm

9-storeys main building and 5-storeys back extension

This building represents a generic upward extension to the Office block typology

Figure 4.9 – Graphical representation of the baseline case and the upward extension chosen to model the office building typology

Methodology | Office | Extensions (2/4)

Retrofit specification scenarios modelled

A set of specifications that considered various levels of performance for fabric and ventilation, heating systems and renewable energy provision were modelled. The performance of these scenarios ranged from ‘business as usual’ approaches to more ambitious ‘ultra-low energy’ levels.

- **Option 1 –** Existing office block with a new upward extension modelled using fabric efficiency based on Part L 2021 building regulations, MVHR for the new extension only, existing gas boiler serving all areas and no PVs.
- **Option 2 –** Existing office block remains unchanged and there is a slight improvement to the fabric efficiency for the new upward extension based on the fabric specifications outlined in in Figure 4.5 on page 48. It is to be noted that some of these specifications have been improved further following good practice.
- **Option 3 –** Same fabric specifications as Option 2 with a change of heating system to VRF (Variable Refrigerant Flow) for the new upward extension only. Solar PVs are added to the extension roof.
- **Option 4 –** Existing office building remains unchanged. Ultra-low energy fabric improvements, a more efficient MVHR and a low carbon heating system (an air source heat pump) are assumed for the new extension only. Solar PVs are added to the extension roof.
- **Option 5 –** The fabric specification for both the existing office building and new extension remain the same as Option 4 with the introduction of an air source heat pump to the whole building. Solar PVs are added to the new extension roof.
- **Option 6 –** Fabric improvements and MVHR are assumed for the whole office building. Solar PVs are added to the extension roof.

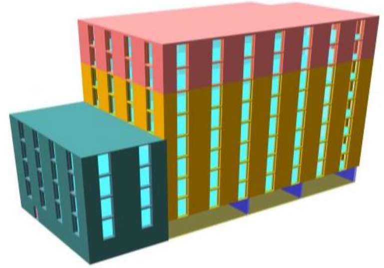
	Option 1			Option 2			Option 3			Option 4			Option 5			Option 6		
Purpose	*Building regulations*			*Low energy fabric (extension only)*			*02 + VRF (extension only)*			*Ultra-low energy fabric, better MVHR and heat pump (extension only)*			*04 + heat pump (whole building)*			*Whole building retrofit*		
FABRIC & VENTILATION																		
	Existing Building	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**
Floors (W/m^2K)	1.00	0.25	0.18	1.00	0.25	**0.12**	1.00	0.25	0.12	1.00	0.25	**0.09**	1.00	0.25	0.09	**0.25**	0.25	0.09
Walls (W/m^2K)	2.10	0.35	0.26	2.10	0.35	**0.18**	2.10	0.35	0.18	2.10	0.35	**0.13**	2.10	0.35	0.13	**0.30**		0.13
Roof (W/m^2K) - flat	1.40	0.25	0.18	1.40	0.25	**0.13**	1.40	0.25	0.13	1.40	0.25	**0.10**	1.40	0.25	0.10	**0.18**		0.10
Windows (W/m^2K)	5.6 (single-glazed)	2.2 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1 (triple glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1 (triple glazed)	**1 (triple glazed)**		1 (triple glazed)
g-value	0.70	0.65	0.40	0.70	0.65	0.40	0.70	0.65	0.40	0.70	0.65	0.40	0.70	0.65	0.40	**0.40**		0.40
Curtain walling	5.6 (single-glazed)	2.2 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1.2 (triple glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1.2 (triple glazed)	**1.2 (triple glazed)**		1.2 (triple glazed)
External Doors (W/m^2K)	2.50	2.20	1.60	2.50	2.20	**1.50**	2.50	2.20	1.50	2.50	2.20	1.50	2.50	2.20	1.50	**1.50**		1.50
Air permeability (m^3/m^2h)	15 (0.45 ACH)	10 (0.3 ACH)	8 (0.22 ACH)	15 (0.45 ACH)	10 (0.3 ACH)	**5 (0.15 ACH)**	15 (0.45 ACH)	10 (0.3 ACH)	5 (0.15 ACH)	15 (0.45 ACH)	10 (0.3 ACH)	**1 (0.04 ACH)**	15 (0.45 ACH)	10 (0.3 ACH)	1 (0.04 ACH)	**5 (0.15 ACH)**		1 (0.04 ACH)
Ventilation system and design	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		**Best practice AHU**	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Best practice AHU	**Best practice AHU**		Best practice AHU
Ventilation system heat recovery efficiency	N/A		0.60	N/A		0.60	N/A		0.60	N/A		**0.85**	N/A		0.85	**0.85**		0.85
Ventilation system SFP	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)		1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)		1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)		**1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)**	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)		1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)		1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	**1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)**		1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)
Demand control ventilation	No		No	No		No	No		No	No		**Yes**	No		Yes	**Yes**		Yes

Table 5 - Example of the six different levels of fabric and ventilation efficiency considered.
The full-sized input and assumption list can be found in Appendix A.4.

Upward extension

6,387 sqm

9-storeys main building and 5-storeys side extension



Demolition and re-building of side extension

It was decided with Camden Council to model an additional case that would involve the demolition and re-building of the office block side extension combined with a new upward extension to the same 9-storey height.

Six different scenarios/combinations of specifications

We modelled six different scenarios of the building by combining various specifications related to fabric and ventilation, heating systems, and solar PVs for the upward extension. Further details can be found in Appendix A.5.

Predictive energy modelling outputs

The buildings were modelled using EDSL TAS Version 9.5.6 software in accordance with the CIBSE TM54 guidance and methodology for evaluating operational energy use. It is important to note that a key principle of this methodology is that the predicted consumption should be taken as a range, which accounts for a level of uncertainty in the operation and management of the building.

Office building partial demolition and extension case modelled

Partial demolition & rebuild

Outward and upward extension (indicated in pink)

7,204 sqm

9-storeys main building

This building represents the generic outward and upward extension to the office building typology

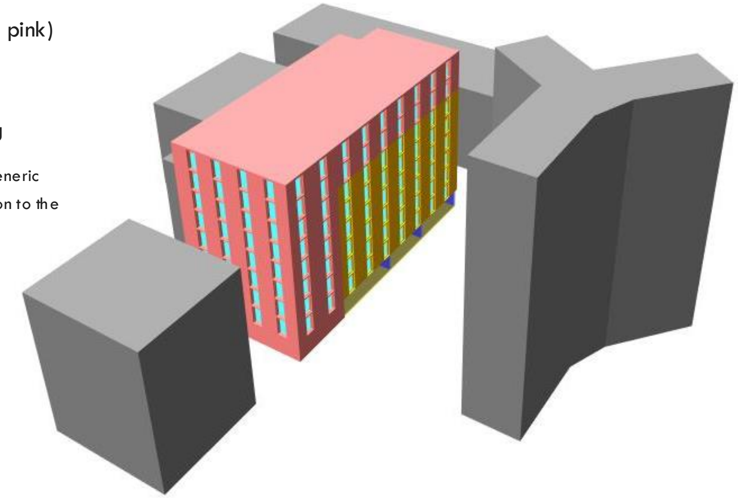


Figure 4.9 – Graphical representation of the outward and upward extension chosen to model

Specification scenarios modelled

A set of specifications which considered various levels of performance for fabric and ventilation, heating systems and renewable energy provision were modelled. The performance of these scenarios ranged from 'business as usual' approaches to more ambitious 'ultra-low energy' levels.

- **Option 1 –** Existing office building with a new upward extension modelled using fabric efficiency based on minimum Part L 2021 building regulations requirement, MVHR for the extension only, existing gas boiler and no PVs.
- **Option 2 –** Existing office block remains unchanged and there is a slight improvement to the fabric efficiency for the new extensions based on the fabric specifications outlined in in Figure 4.5 on page 48. It is to be noted that some of these specifications have been improved further following good practice.
- **Option 3 –** Same fabric specifications as option 2 with a change of heating system to VRF (Variable Refrigerant Flow) for the extensions and the main building. Solar PVs are added to the extension roof.
- **Option 4 –** Existing office building remains unchanged. Ultra-low energy fabric improvements, a more efficient MVHR and a low carbon heating system solution (an air source heat pump) is applied to the new extensions only. Solar PVs are added to the extension roof.
- **Option 5 –** The fabric specification for both the existing office building and new extension remain the same as Option 4 with the introduction of an air source heat pump to the whole building. Solar PVs are added to the extension roof.
- **Option 6 –** Fabric improvements and MVHR provided to the existing office block resulting in a whole building retrofit. Photovoltaic panels are added to the extension roof.

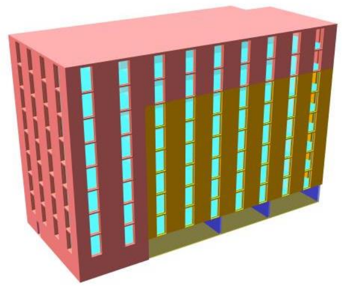
	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*02 + VRF (whole building)*		*Ultra-low energy fabric, better MVHR and heat pump (extension only)*		*04 + heat pump (whole building)*		*Whole building retrofit*	
FABRIC & VENTILATION												
	Existing Building	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**
Floors (W/m²K)	1.00	0.18	1.00	**0.12**	1.00	0.12	1.00	**0.09**	1.00	0.09	**0.25**	0.09
Walls (W/m²K)	2.10	0.26	2.10	**0.18**	2.10	0.18	2.10	**0.13**	2.10	0.13	**0.30**	0.13
Roof (W/m²K) - flat	1.40	0.18	1.40	**0.13**	1.40	0.13	1.40	**0.10**	1.40	0.10	**0.18**	0.10
Windows (W/m²K)	5.6 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	**1 (triple glazed)**	5.6 (single-glazed)	1 (triple glazed)	**1 (triple glazed)**	1 (triple glazed)
g-value	0.70	0.40	0.70	0.40	0.70	0.40	0.70	0.40	0.70	0.40	**0.40**	0.40
Curtain walling	5.6 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	**1.2 (triple glazed)**	5.6 (single-glazed)	1.2 (triple glazed)	**1.2 (triple glazed)**	1.2 (triple glazed)
External Doors (W/m²K)	2.50	1.60	2.50	**1.50**	2.50	1.50	2.50	1.50	2.50	1.50	**1.50**	1.50
Air permeability (m³/m²h)	15 (0.45 ACH)	8 (0.22 ACH)	15 (0.45 ACH)	**5 (0.15 ACH)**	15 (0.45 ACH)	5 (0.15 ACH)	15 (0.45 ACH)	**1 (0.04 ACH)**	15 (0.45 ACH)	1 (0.04 ACH)	**5 (0.15 ACH)**	1 (0.04 ACH)
Ventilation system and design	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	**Best practice AHU**	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Best practice AHU	**Best practice AHU**	Best practice AHU
Ventilation system heat recovery efficiency	N/A	0.60	N/A	0.60	N/A	0.60	N/A	**0.85**	N/A	0.85	**0.85**	0.85
Ventilation system SFP	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)	1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)	1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)	**1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)**	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)	1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)	1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	**1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)**	1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)
Demand control ventilation	No	No	No	No	No	No	No	Yes	No	Yes	**Yes**	Yes

Table 6 - Example of the six different levels of fabric and ventilation efficiency considered.
The full-sized input and assumption list can be found in Appendix A.5.

Upward and outward extension

7,204 sqm

9-storeys main building



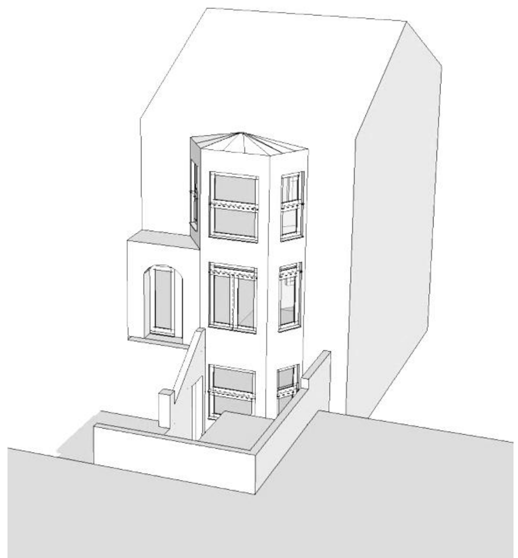
5.0

Technical feasibility

This section outlines the predictive energy modelling results for the various retrofit and extensions scenarios for each typology explored.

5.1

Domestic retrofit and extensions



Domestic retrofit and extensions | Modelling results

Baseline modelling establishes a reference case for comparing alternative scenarios, identifies high impact measures for energy efficiency and emissions reduction, and demonstrates the combined savings potential of whole-house retrofits.

Energy use, emissions, and energy bills of retrofit measures

Using the specifications outlined in Section 4.0 and Appendix A.1, the potential savings of various retrofit measures in terms of energy use, carbon emissions, and energy bills were estimated using the predictive modelling tool Passivhaus Planning Package (PHPP).

The results are illustrated by the graphs on the following pages.

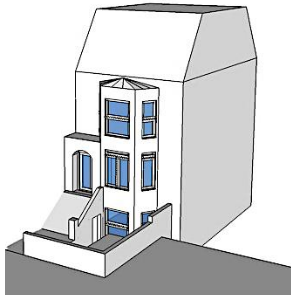
Domestic extensions modelled

Baseline case

185 sqm

3-storeys

This model represents the generic terrace house typology

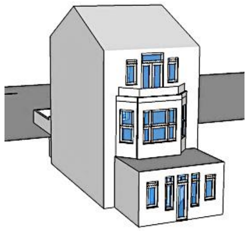


Upward extension

235 sqm

4-storeys

This model represents a typical loft extensions to the terrace house typology

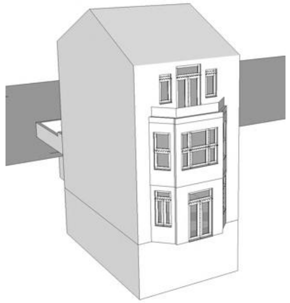


Outward rear extension

200 sqm

3-storeys

This model represents a typical rear ground floor extension to the terrace house typology



Basement extension

245 sqm

4-storeys

This model represents a typical new habitable basement extension to the terrace house typology

Figure 5.1 – Graphical representation of a baseline model of the existing terrace building and three subsequent extensions to the house which have been modelled

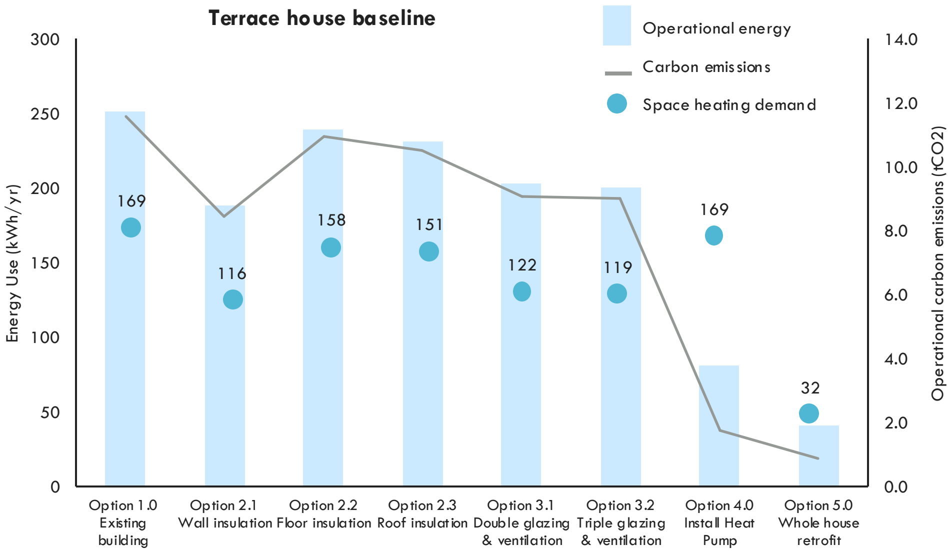


Figure 5.2 – Energy use intensity and carbon emissions across eight retrofit modelling scenarios for the terraced house.

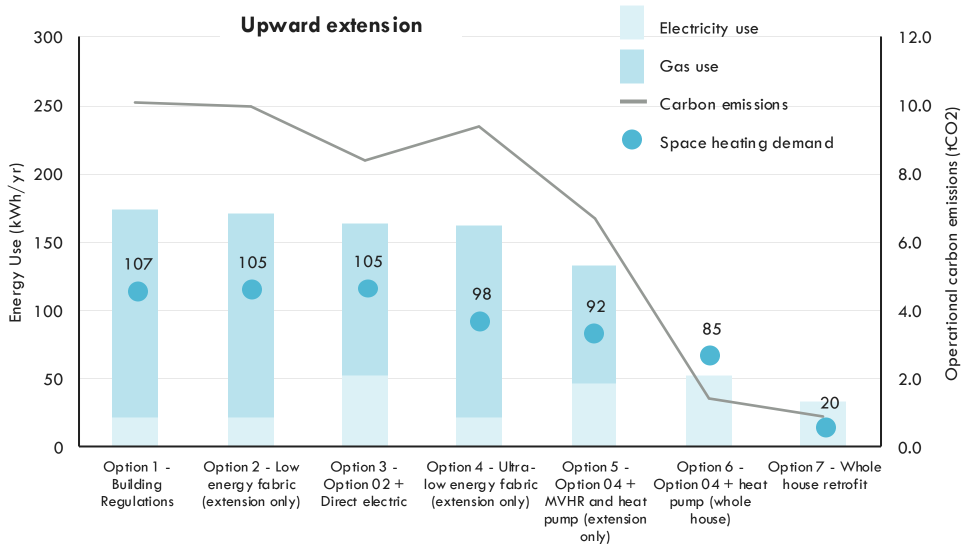


Figure 5.3 – Energy use intensity and carbon emissions across seven modelling scenarios for the upward extension.

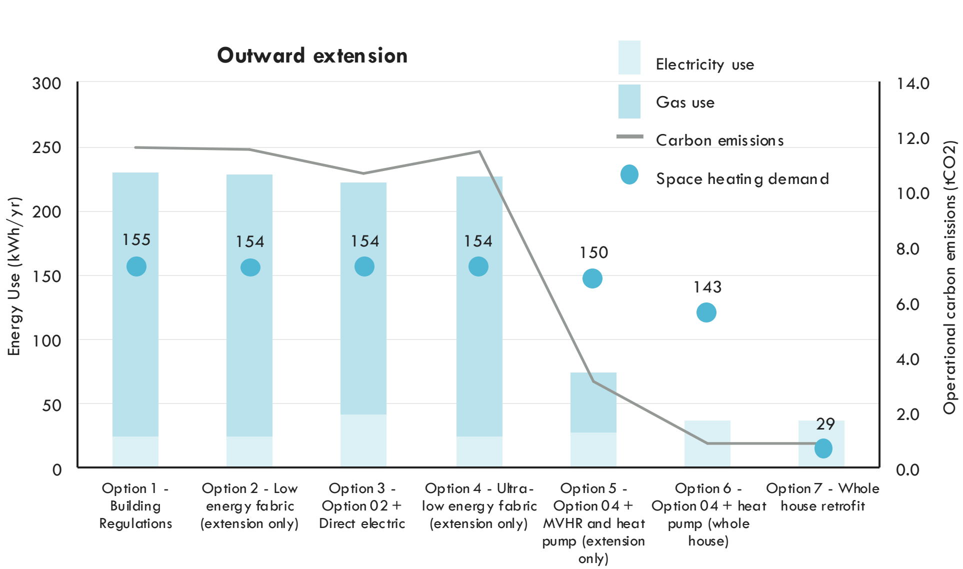


Figure 5.4 – Energy use intensity, space heating demand and carbon emissions across seven modelling scenarios for the outward extension.

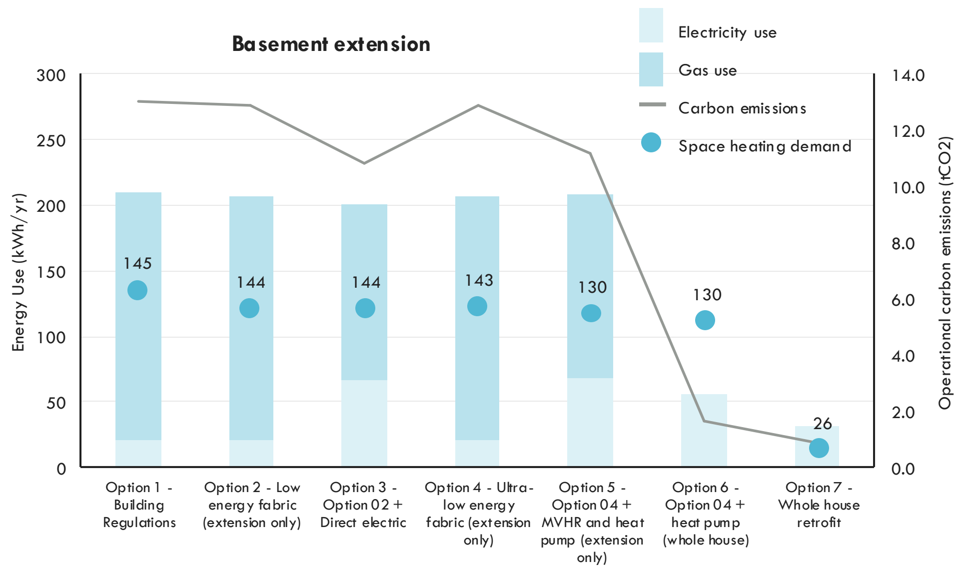


Figure 5.5 – Energy use intensity and carbon emissions across seven modelling scenarios for the basement extension.

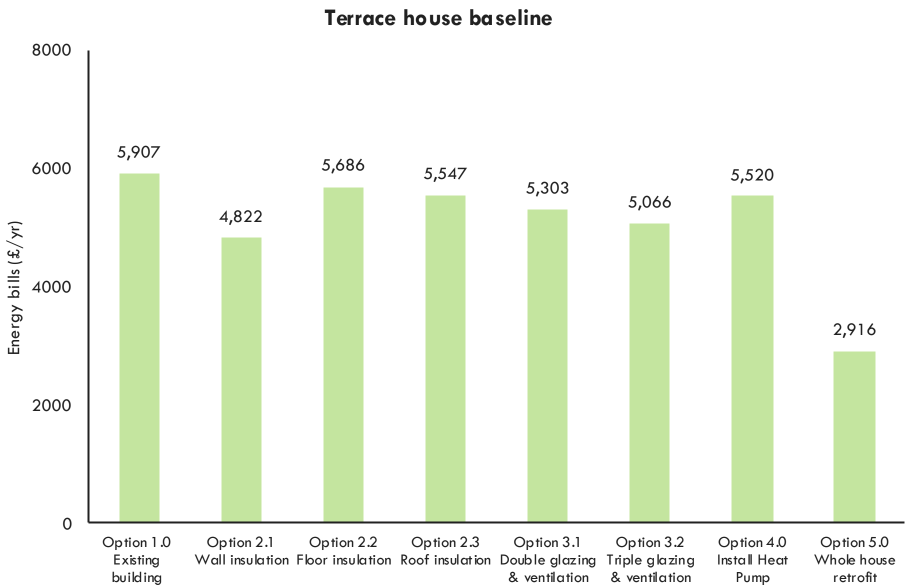


Figure 5.6 – Graph showing the energy bills of the eight modelling scenarios of the Terrace house retrofit measures

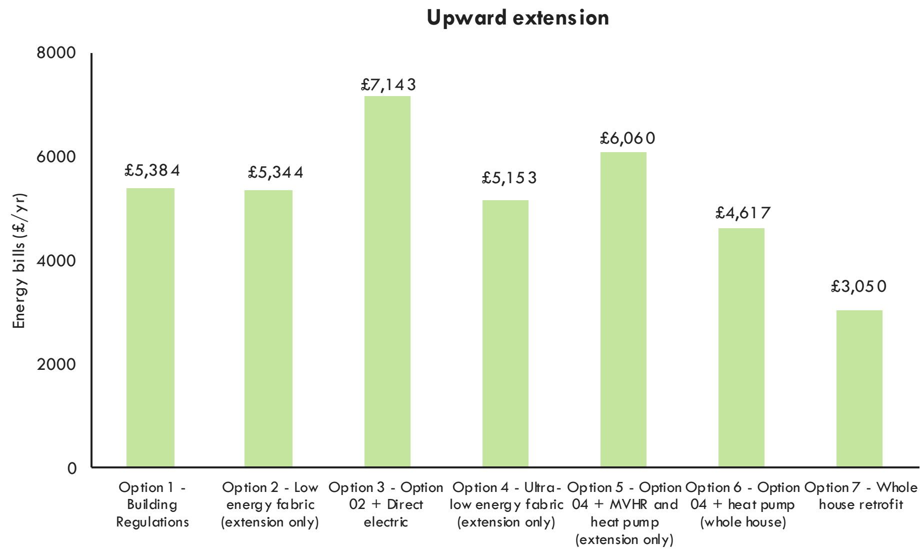


Figure 5.7 - Graph showing the energy bills of the six modelling scenarios of the upwards extension

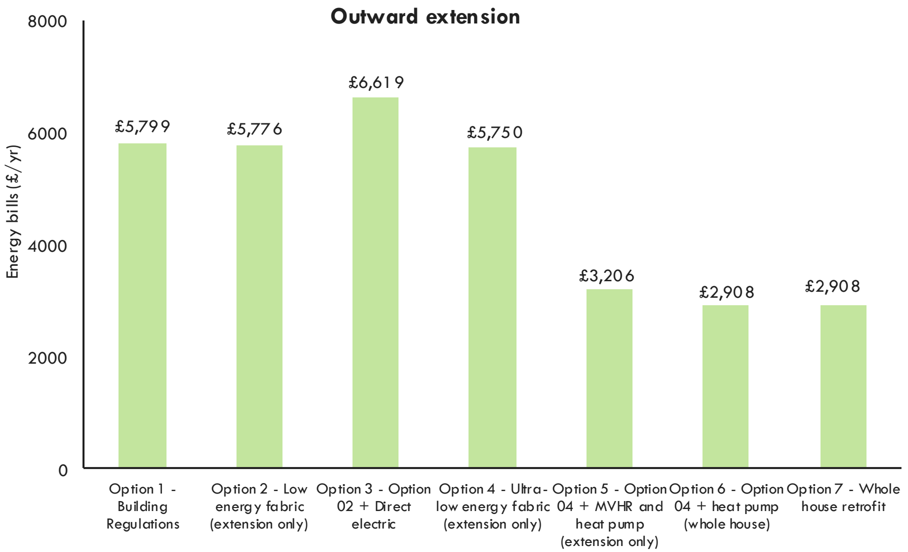


Figure 5.8– Graph showing the energy bills of the six modelling scenarios of the outward extension

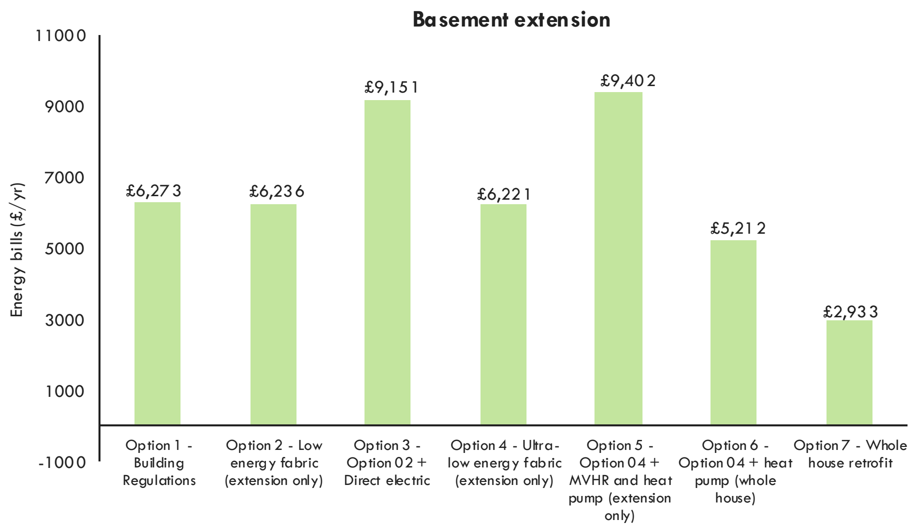


Figure 5.9 - Graph showing the energy bills of the six modelling scenarios of the basement extension

Baseline Terrace

This page summarises the energy performance and bill outcomes of various retrofit scenarios, highlighting key measures, their impact on energy demand, and the effectiveness of heating system upgrades for the existing Terrace house:

- In Figure 5.2, energy consumption and carbon emissions are lower than the existing building showing a **downward trend across the six retrofit scenarios compared to the base case** (option 1 with no retrofits). The only exception is space heating demand for the 'air source heat pump only' case which is not reduced while energy use is significantly lower due to the heat pump's efficiency.

- Options 2.1, 3.1 and 3.2 show that the **wall insulation, double/triple glazing and ventilation improvements** are the key measures required to **reduce the space heating demand** from the base case.

- Option 4 also shows that **installing a heat pump in the building reduces the overall energy consumption even without any fabric or airtightness improvements.** Depending on the priority of a homeowner or landlord, the heat pump installation could be optimised for to reduce the annual consumption of the building, however a balanced approach inclusive of fabric improvements is recommended to ensure the building is more energy efficient.

- Figure 5.2 shows that while a low carbon heating system drastically reduces energy use, it also has a modest effect on the energy bills relative to the baseline due to the current cost of electricity.

- Option 3.1 and 3.2 show there is only a small difference between the impact of double-glazed windows and triple glazed windows. However, triple-glazed windows would lead to savings in energy bills and better comfort (both thermally and acoustically).

- A comprehensive whole-house retrofit effectively reduces both energy use and emissions due to an efficient thermal envelope, a low carbon heating system and integrated renewable technologies (solar PVs). The base case results suggest different prioritisations logics: a heating system replacement for maximum energy savings and emission reductions or external wall installation for reduced space heating demand.

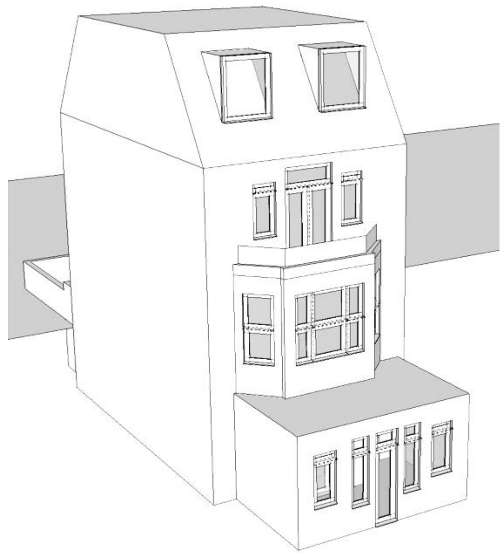
Outward, Upward & Basement Extensions

This page summarises the energy performance and bill outcomes of the various extensions and retrofit scenarios for the Terrace house:

- There is marginal improvements between Options 1 through 4 for all the extension scenarios for both energy use, also known as energy consumption, and space heating demand. This suggests that despite specifying best practise fabric, mechanical ventilation and low carbon heating solutions for the extension this has minor impact on the building as a whole.
- There is negligible difference between the energy cost in Option 1 (building regulations specification) and Option 4 (only Ultra-low fabric specification to the new extension with no changes to the ventilation and heating systems)..
- For all extensions scenarios, there is moderate decrease in energy cost between Options 3 and 4 due to the current cost of electricity compared to gas and the inclusion of a direct electric system in Option 3.
- In Figure 5.4 , the results highlight that the outward rear extension benefit most from having a standalone best-practice heating solution i.e. air source heat pump, which leads to a significant reduction in energy use, as the air-to-air heat pump efficiently meets the heating needs of the new, well-insulated space without relying on the older, less efficient heating system of the main house. In both the upward and basement extensions, a whole house heat pump system ensures that these extensions receive adequate low carbon heat in line with the rest of the building. When a whole-house air source heat pump is introduced, it allows for a comprehensive upgrade to the main building's heating system, which is particularly beneficial for spaces like basements and upper floors that rely on consistent heating.
- From a carbon perspective, it is evident that the **electrification of the property** through the introduction of **localised low carbon heating solutions** e.g. direct electric and air source heat pumps, drives down the operational carbon emissions.
- Generally, improvements on the basement extension from Option 1 through to 7 reveal that energy bills are higher than other extensions scenarios. Unlike above-ground rooms, basements receive little to no solar gains and have high heat losses. Hence the space heating demand not improving between Options 5 and 6 despite overall energy consumption decreasing significantly.

5.2

Conversion of a terrace house into flats



Terrace to Flats

This page summarises the energy performance and bill outcomes of the conversion of the Terrace house to flats using an upward and outward extensions and implementing some retrofit measures:

- Figure 5.10 show that similarly to the extension scenarios, there is **minimal improvement shown in Option 2 with fabric only measures against the minimum requiremets of building regulations.**
- **Carbon emissions follow a downward trend, with the steepest decline at Option 5 due to electrification.** The whole house retrofit (Option 6) shows the effectiveness of transitioning from gas to electric heating systems, combined with improved insulation, for maximizing energy efficiency and emissions reduction in buildings.
- While a low-carbon heating system drastically reduces energy use, it also leads to higher energy bills due to the current cost of electricity. This is highlighted by Option 3 where the energy bills increase due to direct electric heating system for the extension only followed by a slight decrease due to air-source heat pumps in option 4. Therefore, the air-source heat pump presents a more cost-effective low carbon heating solution.
- Figure 5.11 shows that **the ground floor unit consistently has the highest bills.** This is likely due to its larger floor area compared to the top floor unit.

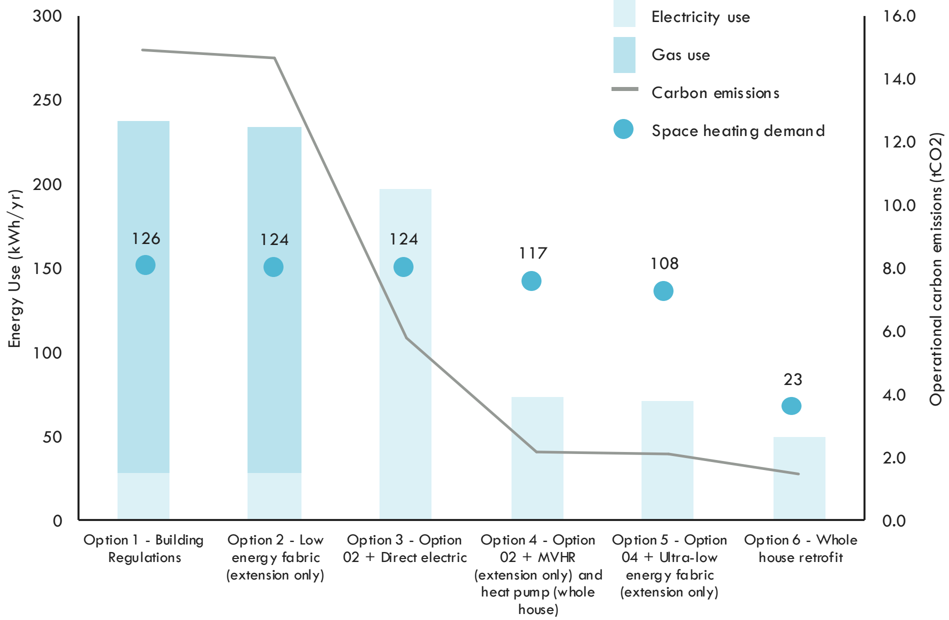


Figure 5.10 – Energy use intensity and carbon emissions across six modelling scenarios for the conversion of terraced house to flats.

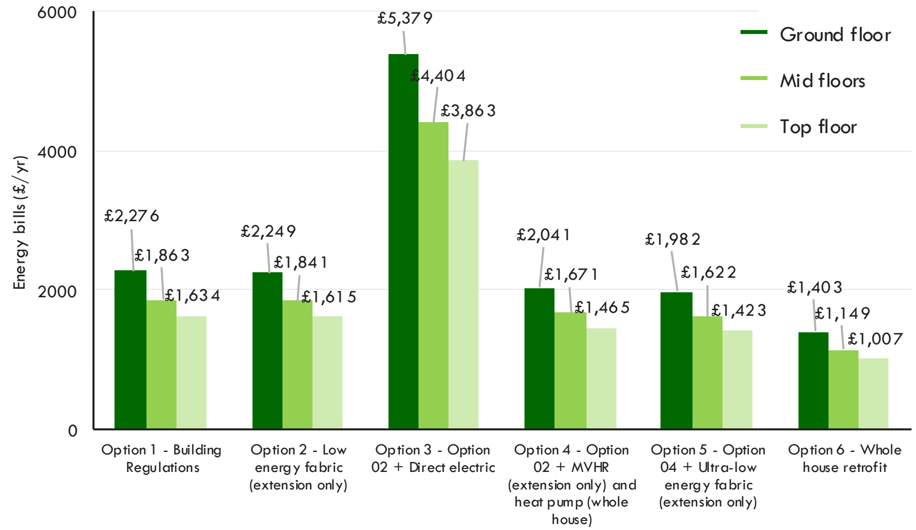
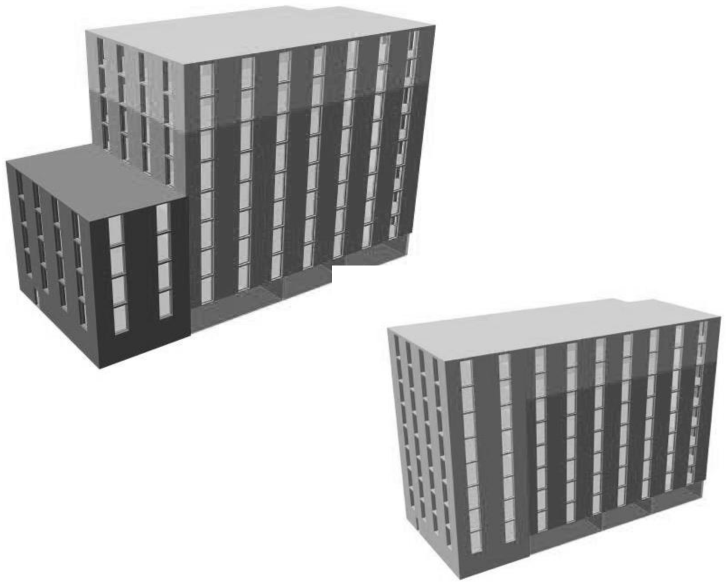


Figure 5.11 – Graph showing the energy bills of the six modelling scenarios for the conversion of terraced house to flats. The energy bills have been split across the 3 flat units formed.

5.3

Non-domestic retrofit and extensions



Addressing Modelling Uncertainties

As per the CIBSE TM54 methodology, a low, mid and high case have been set up and modelled, with the assumptions that differentiate them clearly detailed in Appendix A.4.

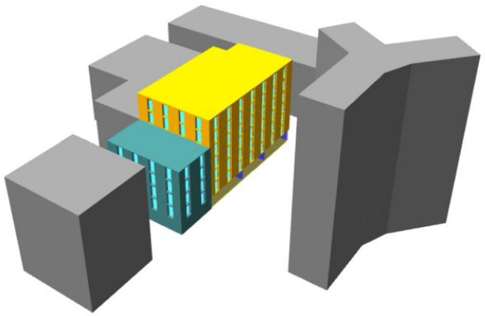
The scenarios represent the uncertainties around the operational and management aspects of the building. For example, how and when the building is used, are the building services properly turn off/down during unoccupied hours, is simultaneous heating and cooling allowed to happen. Scenario testing gives an indication of the range of variation from these uncertainties.

The mid-case case is considered the most average / realistic estimate of energy use assuming common occupancy patterns and reasonable assumptions around the control of building services.

Energy use, emissions, and energy bills of retrofit measures

Using the specifications outlined in Table 7 and Appendix A.4, the energy use, carbon emissions, and indicative energy bills of the baseline case were estimated using EDSL TAS software in accordance with CIBSE TM54. The overall results are illustrated in the graphs on the following pages.

Office building extension case modelled

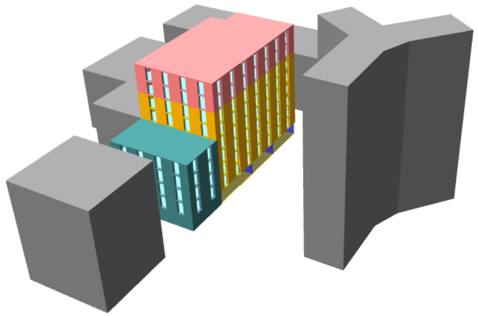


Baseline case (indicated in yellow) with existing extension (indicated in blue)

5,192 sqm

7-storeys main building and 5-storeys back extension

This building represents a generic office block typology

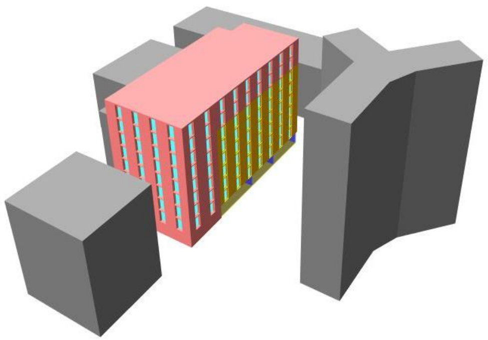


Upward extension (indicated in pink)

6,387 sqm

9-storeys main building and 5-storeys back extension

This building represents a generic upward extension to the Office block typology



Partial demolition & rebuild

Outward and upward extension (indicated in pink)

7,204 sqm

9-storeys main building

This building represents the generic outward and upward extension to the office building typology

Figure 5.12 – Graphical representation of the baseline case, the upward extension and the demolition and rebuild scenarios

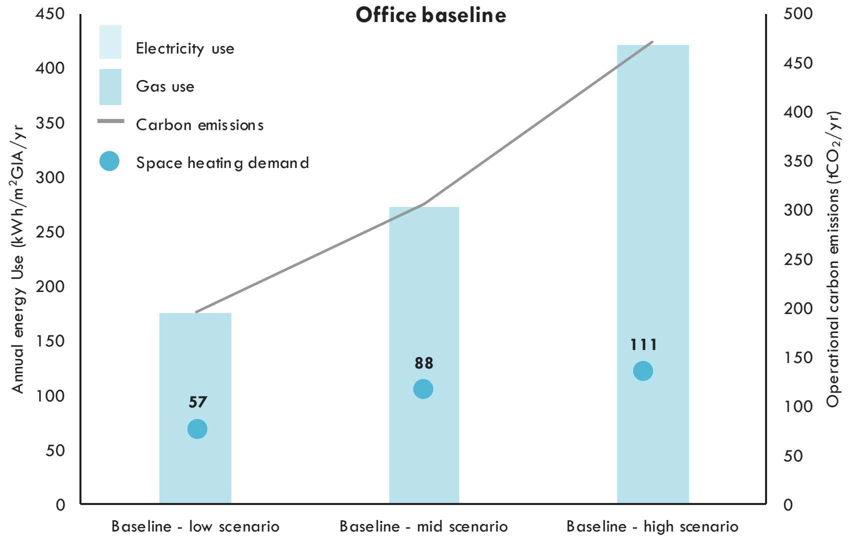


Figure 5.13– Energy use intensity and carbon emissions across the low, mid and high scenarios of the baseline case.

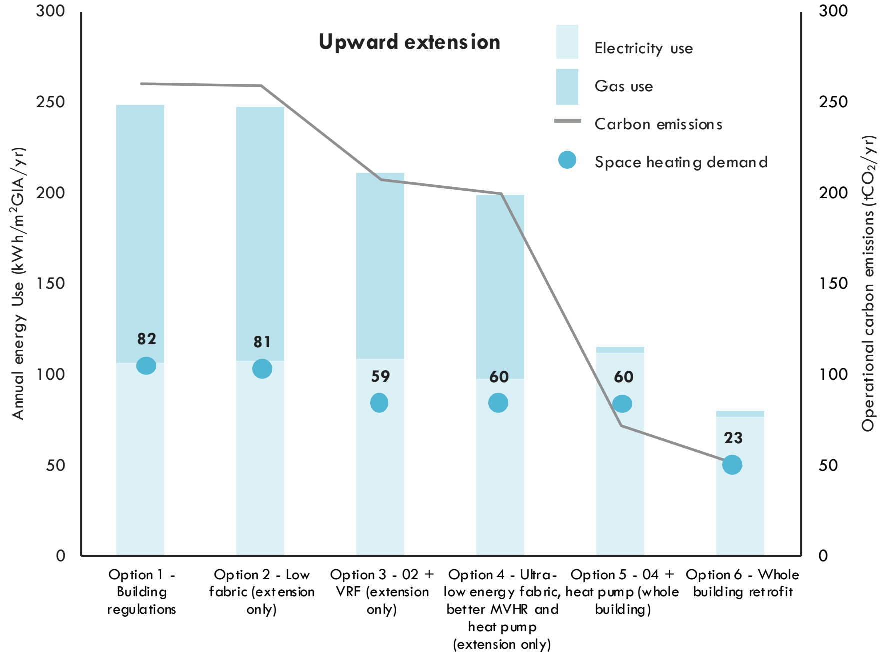


Figure 5.14 - Energy use intensity and carbon emissions across six modelling scenarios for the outward extension (please note: this does not account for PV energy generation)

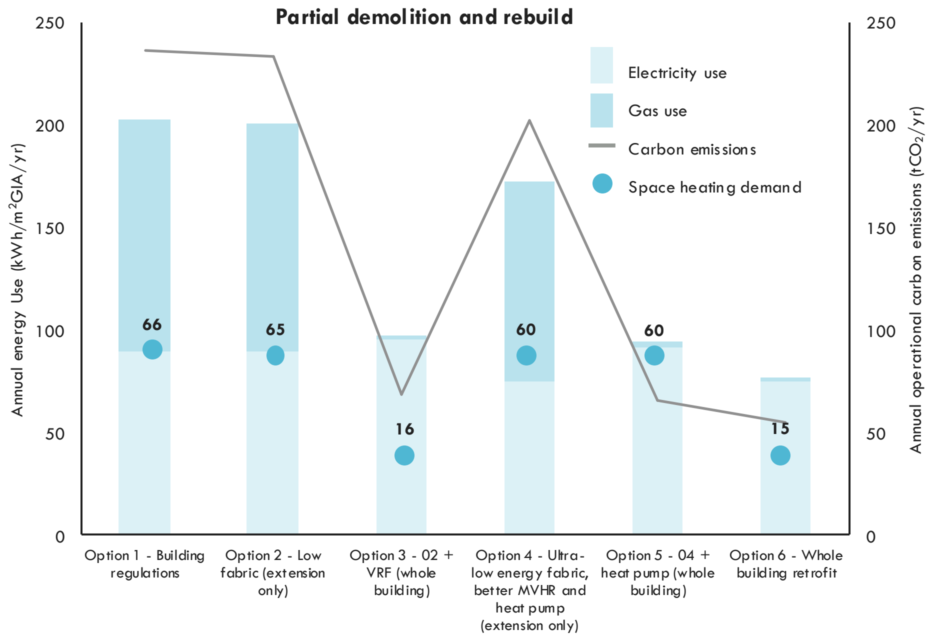


Figure 5.15- Energy use intensity and carbon emissions across six modelling scenarios for partial demolition and rebuild.

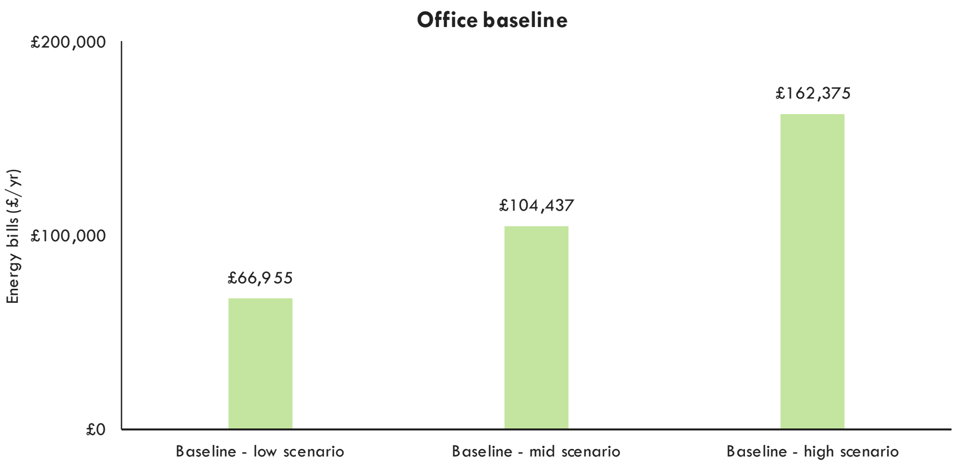


Figure 5.16 – Graph showing the energy bills of the low, mid and high scenarios of baseline office building

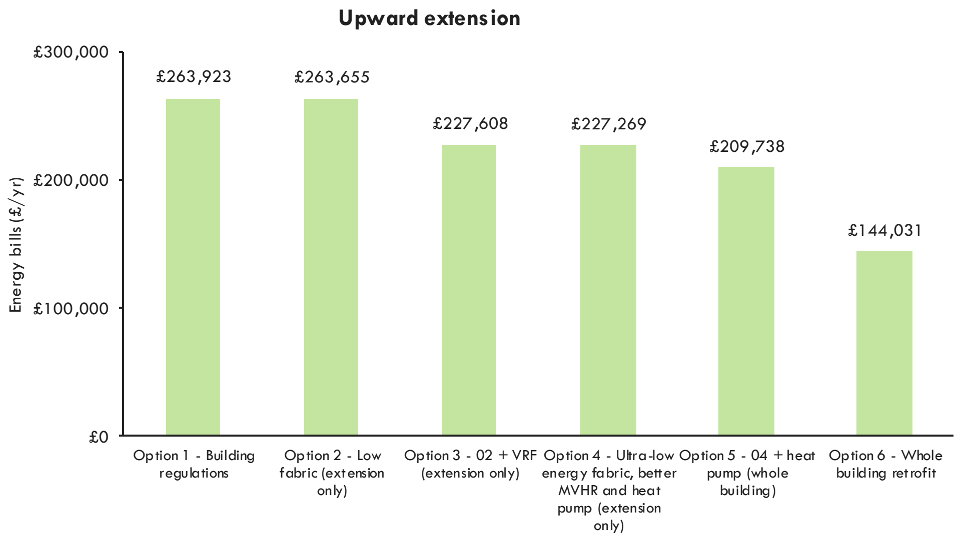


Figure 5.17 - Graph showing the energy bills of the six modelling scenarios of the upwards extension

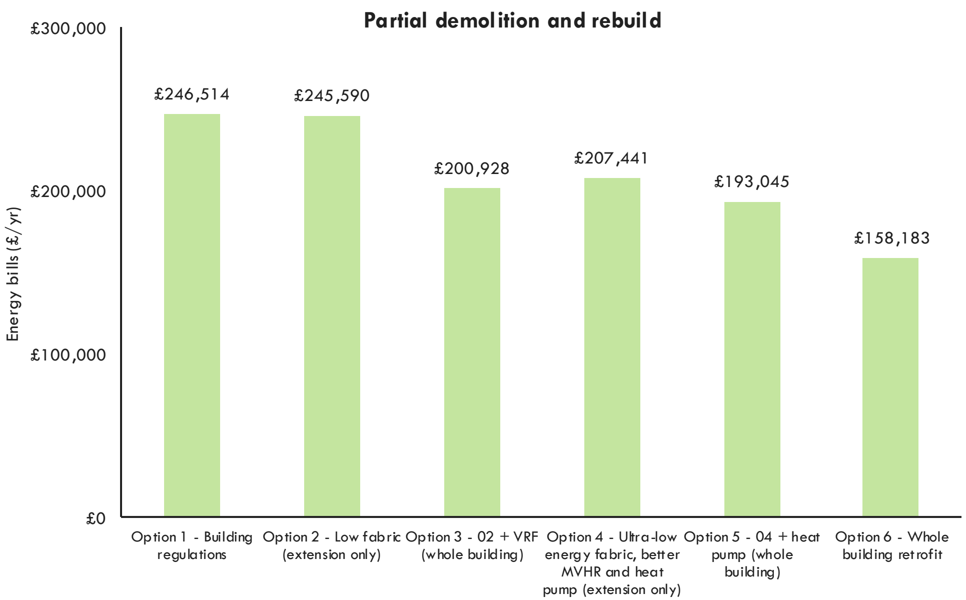


Figure 5.18 – Graph showing the energy bills of the six modelling scenarios for partial demolition and rebuild.

Baseline Office

This page summarises the energy performance and bill outcomes of various retrofit scenarios to the existing office building and the demolition and rebuild scenario:

- In Figure 5.13, energy consumption shows an upward trend across the three scenarios. **This indicates the significant impact that certain assumptions such as occupancy hours, internal gains, ventilation profiles, and management considerations can have on predicted energy use.**
- Figure 5.16 shows a corresponding trend; the energy bills are significantly higher for the same building when using the high case assumptions.
- Although the energy use increases significantly across the scenarios, the rate of change of space heating demand is relatively marginal and is therefore not as sensitive to the variations in assumptions.

Demolition & Rebuild – Upward Extension

- For the upward extension, the energy consumption shows a downward trend across the five retrofit scenarios compared to the base case (option 1 with no retrofits). The results suggest prioritising heating system replacement over typically intrusive fabric measures for maximum energy savings and carbon emission reductions. The greatest reduction in total energy consumption occurs in Options 5 and 6 when the heating system for the whole building is changed to an air source heat pump.
- Carbon emissions show a consistent downward trend, with the sharpest decline occurring at Option 5 for both the extension and the partial demolition and rebuild, as well as at Option 3 for the partial demolition and rebuild case. This is attributed to full electrification, which eliminates the need for fossil fuels, allowing the building to fully benefit from grid decarbonisation and on-site renewables.
- For partial demolition and rebuild, the energy consumption shows a downward trend across the first three scenarios compared to the base case (option 1 with no retrofits). Option 3 has a sharp drop in energy/carbon due to the whole building being fully heated by a VRF system which is highly efficient and uses heat pump technology to transfer heat. The fourth option shows an increase as the existing building's heating system reverts back to a gas boiler.
- **However, once the heat pump is modelled for the whole building (option 5) a reduction in energy use is noted.** The greatest reduction in total energy consumption occurs in Options 3, 5 and 6 when the heating system of the whole building is changed to low carbon heating. For the upward extension case, the whole-building retrofit (Option 6) shows the further benefit of minimising heat demand through improved insulation, air tightness and other energy performance fabric upgrades. Changing to low carbon heating (VRF / air-to-air heat pump) in the extension also results in a 21% reduction in carbon emissions (Option 1 to Option 3).
- The space heating demand generally mirrors the energy use trend, with the exception of Option 5 in the demolition and rebuild case, this is likely due to the substantial area of extended floor spaces relative to the retained building.
- **Figure 5.14 and 5.15 show that a low-carbon heating system applied to the whole building which drastically reduces energy use, also leads to a notable decrease in energy bills (Options 3 and 5).** However, a comprehensive retrofit, including fabric improvements (Option 6), enhances the thermal envelope's performance, helping the heating system achieve its expected efficiencies and therefore reduces energy bills even further.

6.0

Cost assessment

This section details the provides the likely cost associated with the various retrofit and extensions scenarios for each typology explored.

Assessment of construction costs affected by policy options

The cost analysis identifies the variance between the baseline and the enhanced specifications for elements affected by the operational energy/carbon policy options.

Costs included in this study reflect the design of each archetype. Actual costs incurred on specific projects will vary depending on detail of design, specification and procurement processes, nonetheless these cost allowances are deemed representative for policy development purposes.

Assessment of overall construction costs to deliver a project

Elements not materially affected by energy or carbon policies, e.g. substructure, roof coverings, kitchen, bathrooms, etc are not costed in detail. These costs were incorporated within a ‘benchmark business-as-usual cost’ estimated using a typical whole building construction cost rate per m^2 for each type of refurbishment / change of use activity and building type.

The business-as-usual cost assumes a typical design and fitout for each space. Actual project costs could be higher or lower for a variety of regions. For example, the use of bespoke fitouts or premium materials.

Cost data source and price year

Costs were estimated using Currie & Brown’s experience of delivering retrofit and extension projects and from their cost datasets for energy efficiency and low carbon technologies. These datasets include information from market prices, specific market testing and first principles cost planning by specialist quantity surveyors.

Costs reflect a London cost base inclusive of ‘oncosts’ (see below), but excluding design fees, land, planning, s106 and other non-construction related development costs. The costs are based on Q2 2024.

Oncosts

In addition to the costs of undertaking the construction works (eg materials, labour, etc) there is also an allowance for oncosts. Oncosts are expenses incurred in delivering a project and form part of the price to the building owner. These oncosts include 7% on top of the construction cost for preliminaries such as site set up (including welfare facilities, hoarding, materials storage, etc) and management of the construction process. A further 6% of the combined construction and preliminaries cost for contractor overheads and profits and a contingency allowance of 5%.

These oncosts are incorporated within the overall costs shown for each policy option.

Scope

The costs of meeting each of the specifications comprising the different suggested retrofit measures to incorporate in the various extension scenarios are determined based on a defined scope of works that includes each component and / or process required to deliver a given performance standard.

Cost variations due to design and material preferences

For example, the cost of meeting a given U-value for external walls is based on each component in a wall designed to deliver that performance standard (plasterboard, battens, blockwork, insulation, wall ties, cavity trays and closers, damp proof membranes and brickwork). In many scenarios only one or a few components change between performance specifications, in the case of external walls this is typically the thickness of the insulation layer and other components linked to the width of the wall cavity such as wall ties, cavity trays and closers.

Certain specification items are subject to potentially large variations in cost dependent on design or preference. For example,

- windows - where new timber sash windows installed; these will be substantially more expensive than an equivalently performing uPVC casement window. In this study costs assume medium quality uPVC windows with double or triple glazing units, for triple glazing this is likely to require a casement / 'mock sash' configuration as triple glazed sashes are more expensive, and U-values often compromised to reduce the depth of each sash.
- walls – the total cost of a wall meeting a given U value will depend on the type of construction, particularly the specified external leaf / cladding option. There can be a substantial variation in costs between and within specifications (eg between types of brickwork).

Notwithstanding the above variabilities the variation in costs between different performance levels are deemed representative of a range of specifications. This is because although the total cost of the element may vary, the cost differential for the component driving energy performance, e.g. glazing unit or insulation thickness is relatively consistent.

In some instances, cost assumptions are based on typical £m2 allowances due to the high-level nature of the building design. For example, costs for lighting or fan coils in the office building / extensions. In these instances, we have used typical practice allowances based on an assumed density of fittings (eg one fan coil per c.35m^2 floor area) to estimate costs for a typical fitout.

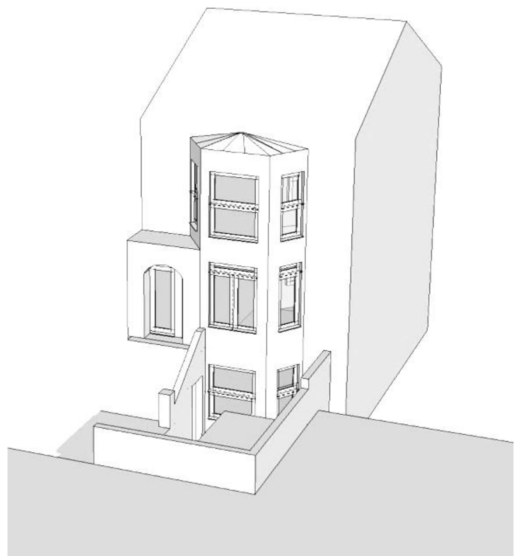
Heating System Upgrades and Cost Considerations

Where a modelled scenario includes a change in heating system type (eg from gas boiler to air source heat pump) our costs include allowances for removal of existing plant, installation and commissioning of new plant with any typical works to system controls / pumps etc. It is assumed that the new plant can be installed in a suitable location and that no material structural alterations or other work is required to enable this.

In some instances, the installation of an air source heat pump in an existing home may require adjustments to the number / size of radiators within a property to ensure sufficient heat output with lower temperatures in each radiator. To take account of the potential need for additional radiator area and allowance of ½ of the cost installing new radiators in a home is included to account for replacement of some existing radiators with those with a greater output (eg from a one panel to a double panel radiator), it is assumed that these new radiators will have the same width as the existing panels and can therefore be installed with minimal work to existing distribution pipework.

6.1

Domestic retrofit and extensions



The cost for the terrace house assumes that only energy efficiency retrofit work is done to the home with no increase in floor area or wider work to internal finishes and layout other than redecoration where needed to 'make good'. It is assumed that the household stays in the home throughout the retrofit works.

Figure 6.1 shows he additional costs of undertaking the different levels of retrofit work to the terraced house archetype. The retrofit specifications for each scenario are those shown in Appendix A.1.

Costs are split into those relating to work to the building fabric, ventilation, heating and hot water and finally the addition of renewable energy generation in the form of photovoltaic panels.

Window replacement (either triple or double) are the most expensive individual retrofit measures. The upgrades to windows also require enhancement to the home ventilation system which further increases the costs of these options.

Installation of an air source heat pump without wider retrofit works to the building fabric is estimated to cost around £13,000 and this includes an allowance of nearly £3,500 (£19 per m^2 net floor area) for upgrading the internal radiators in the home to enable lower temperature heating to operate effectively.

Underfloor insulation is estimated at £5,000 (£27 per m2 net floor area) and includes for a spray insulation under the suspended timber floor but excludes and reinstatement of floor coverings.

Roof insulation is the least expensive of the options modelled at around £3,000 (£17 per m^2 net floor area), this includes only additional insulation, improvement to loft ventilation and a new loft hatch. If OSB boarding over the loft insulation were included to enable storage in the loft with would more than double the cost of the measure to around £7,000.

The whole house retrofit package cost is around £75,000 for this home or £412 per m^2 of net floor area.

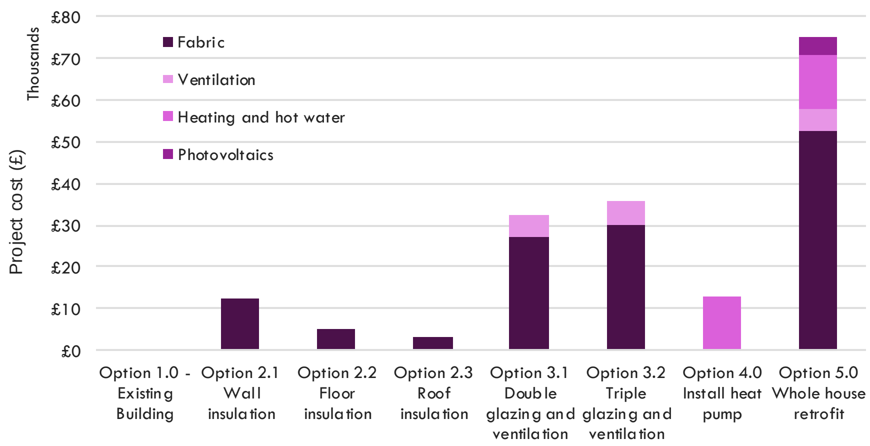


Figure 6.1 – Capital costs across seven modelling scenarios for the terraced house. New windows (triple or double glazed) and ventilation have the highest individual costs followed by installation of an ASHP (with partially replacement of existing radiators), and then external wall insulation. Underfloor insulation and loft insulation are less expensive. The whole-house retrofit (7), combines fabric improvements, new ventilation, heating and a 4kWp.photovoltaic system.

Figure 6.2 illustrates the cost of undertaking the outwards, upwards or downwards extension projects to each of the seven performance levels described in Appendix A.2. The figure shows the percentage increase in cost in comparison to undertaking the retrofit works to minimum regulatory requirements only (Option 1).

Table 7 shows the baseline costs of each extension when built to minimum regulatory requirements

Extension	Upwards	Outwards	Downwards
Baseline budget cost per m^2 for a typical extension built to minimum regulatory requirements	£2,500	£2,900	£2,900
Area (m^2)	18	50	62
Estimated project cost for Option 1	£45,000	£145,000	£179,800

Table 7 – Summary of cost assessment scope for the Terrace extensions

For each extension option, enhancing the fabric specification of the extension only has a relatively small impact on the capital cost, from less than 1% to around 3% for Options 2 to 4. The installation of direct electric heating in lieu of extending the wet heating system from the existing home has little or no impact on capital costs and may be marginally less expensive to install.

The inclusion of a heat pump and MVHR for the extension only increases costs by £7,500-£9,500 this is a larger proportion of the baseline project cost for the upwards extension because this is a smaller and less expensive project.

If the extension project is built to ultra-low fabric standard and includes replacement of the heating system in the whole house (Option 6) costs are increased by between £17,000 and £22,000. Where a whole house retrofit is included in addition to an extension to the ultra-low fabric specification (Option 7) costs are increased by between £69,000 and £75,000.

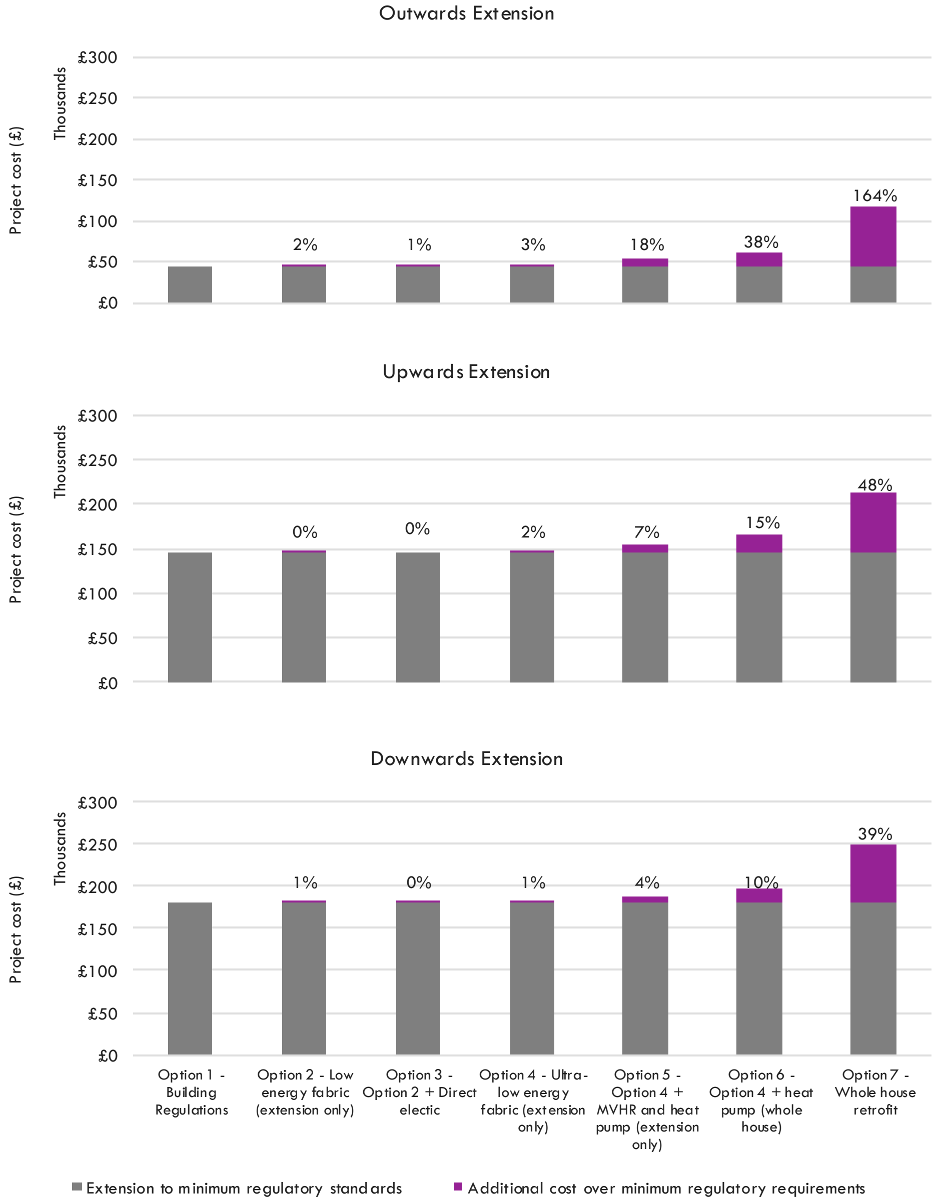


Figure 6.2 – Capital costs across six modelling scenarios for the terraced house.

6.2

Conversion of a terrace house into flats

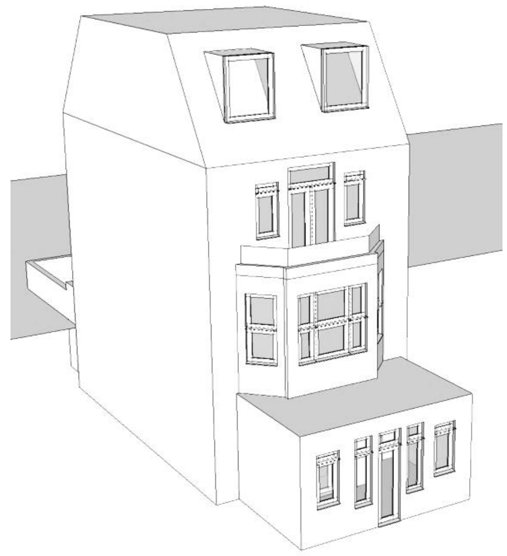


Figure 6.3 illustrates the cost of undertaking both the upwards and outwards extension projects flats, converting the terrace house to four individual flats. The analysis shows the costs of these works being undertaken to each of the seven performance levels described in Appendix A.3.

Table 8 shows the baseline costs of each extension, and the conversion works, when undertaken to minimum regulatory requirements

Scope	Upwards extension	Outwards extension	Conversion to 4 flats
Baseline budget cost per m^2 for standard practice	£2,500	£2,900	£2,500
Area (m^2)	18	50	182
Estimated baseline project cost	£45,000	£145,000	£455,000

Table 8 – Summary of cost assessment for conversion of a Terrace house to flats

For Option 2 has a very small (<0.1%) impact on overall project costs with a total uplift of under £1,000 on a total budget of nearly £700,000. The small increase is a result of relatively modest increases in performance specifications for the extensions only which comprise a relatively small proportion of the total project.

For Option 3 there is a slight (<0.1%) cost saving resulting from the use of direct electric heating systems in comparison to the installation of four new boilers and separate hydronic (water based) heat distribution and radiators in each flat. If some of the existing heating pipework in the house can be reused in the new flats, then the costs are likely to be equivalent, but it is assumed that a wholesale replacement of systems is included as part of the conversion project.

Option 4 results in a cost premium of c.3% over a project built to minimum regulatory standards. Costs are increased due to the inclusion of separate MVHR units and ducting in each flat, four separate air-to-air heat pump units and an increase in fabric standards. Where air to water heat pumps are installed instead of air-to-air units costs increase further to £43,000 or 7% , more than the cost of a project build to minimum regulatory requirements.

If a whole house refurbishment (Option 6) is included as part of the project, this increases costs by £86,000 or 13% of the Option 1 cost. This is a result of the additional cost of works to windows and other fabric items in the existing home.

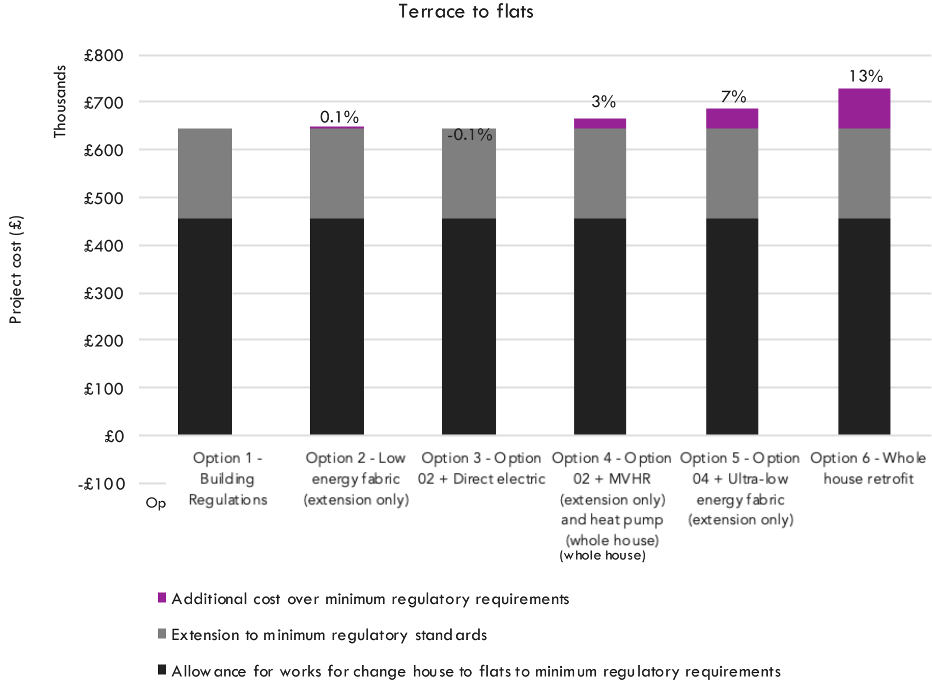
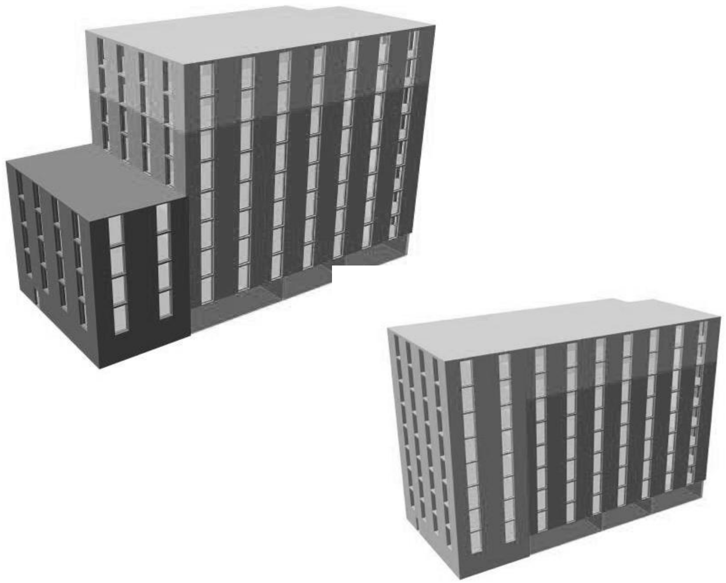


Figure 6.3 – Capital costs across seven modelling scenarios for conversion of the terraced house to four flats together with extensions to roof and at the ground floor.

65.3

Non-domestic retrofit and extensions



Cost assessment | Office building | Extension

Figure 6.4 illustrates the cost of undertaking the upwards extension project to each of the six performance levels described in Appendix A.4. The figure shows the percentage increase in cost in comparison to undertaking the retrofit works to minimum regulatory requirements only (Option 1).

Table 9 shows the baseline costs of the extension when undertaken to minimum regulatory requirements

Extension	Existing extension and construction of new upward extension
Benchmark budget cost per m^2 for extension build to minimum regulatory requirements	£3,500
Area of extension (m^2)	1,195
Estimated baseline project cost	£4,200,000

Table 9 – Benchmark cost for the Large Office upward extension case

Option 2 is estimated to result in a cost premium of c.£18,000 or 0.4% over a building regulations compliant baseline. For Option 3, this cost increases to c.£25,000 or around 0.6% more and the Option 1 cost. Option 4 includes a higher fabric specification, heat recovery ventilation and an air source heat pump for the extension only. These measures increase the project cost by £296,000 compared to Option 1, an increase of 7%. If the measures in Option4 were extended to include the installation of an air source heat pump for the whole of the existing office building, then the cost premium over Option 1 increases to £896,000 or 21%. This is a result of the significant cost of new heating and cooling plant serving the whole of the 5,200 m2 net internal area of the existing office.

Extending the scope of works to include a whole building retrofit of the existing office increases the project cost by c.£3.30million or 79% of the Option 1 cost.

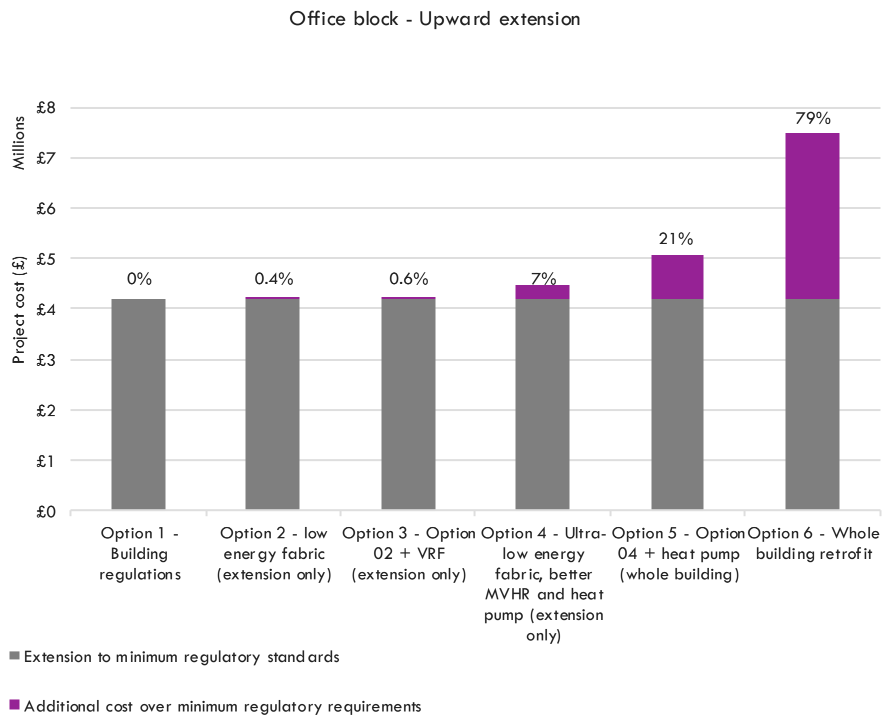


Figure 6.4 – Project costs for six options for delivering an upward extension on the roof of an office block.

Figure 6.5 illustrates the cost of undertaking a new lateral and vertical extension to the office block including partial demolition of a pre-existing extension. The analysis shows the costs of meeting each of the six performance levels described in Appendix A.5 and the percentage increase in cost in comparison to undertaking the retrofit works to minimum regulatory requirements only (Option 1).

Table 10 shows the baseline costs of each extension when undertaken to minimum regulatory requirements

Extension	Demolition of existing extension and construction of new lateral and vertical extension
Baseline budget cost per m^2 for standard practice	£3,500
Area of extension (m^2)	2,012
Estimated baseline project cost	£7,000,000

Table 10 –Benchmark cost for the Large Office demolition and extension case

Option 2 is estimated to result in a cost premium of c.£43,000 or 0.5% over a building regulations compliant baseline. For Option 3, this cost increases to c.£54,000 or around 0.6% more and the Option 1 cost. Option 4 includes a higher fabric specification, heat recovery ventilation and an air source heat pump for the extension only. These measures increase the project cost by £491,000 compared to Option 1, an increase of 5%. If the measures in Option4 were extended to include the installation of an air source heat pump for the whole of the existing office building, then the cost premium over Option 1 increases to £1.09 million or 12%. This is a result of the significant cost of new heating and cooling plant serving the whole of the existing office.

Extending the scope of works to include a whole building retrofit of the existing office increases the project cost by c.£3.18million or 35% of the Option 1 cost.

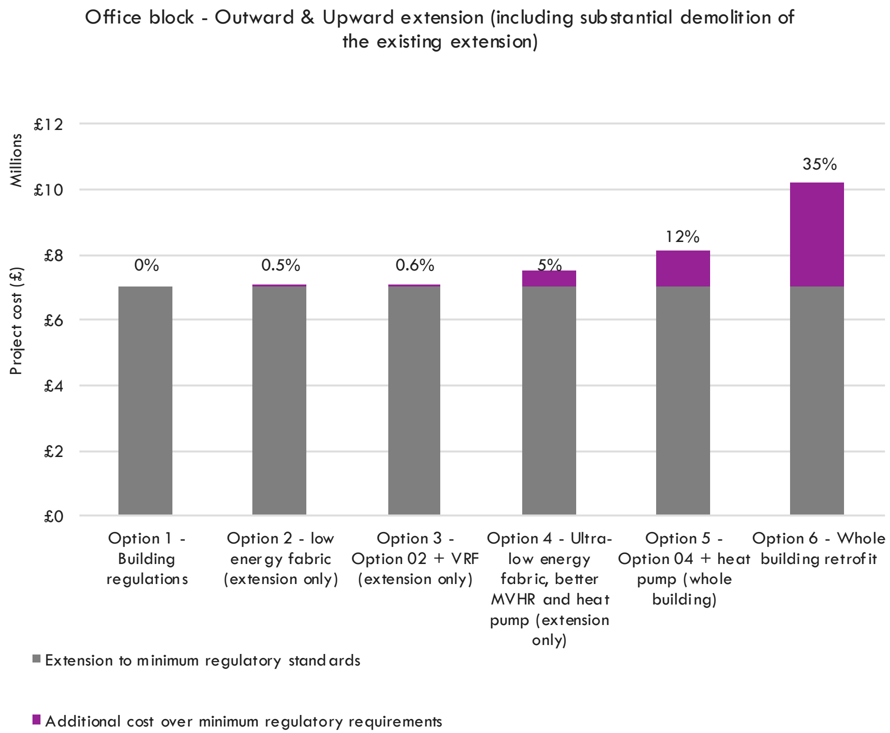


Figure 6.5 – Capital costs across six modelling scenarios for partial demolition of an existing extension and construction of a new extension to the side and roof of the office block building.

7.0

Summary of key findings

This section provides an overview of the recommendations for each typology and scenarios. It also provides indicative quantified recommendations on potential space heating demand and energy use intensity requirements.

- Options 2.1, 3.1, and 3.2 demonstrate that prioritising wall insulation, upgraded windows and ventilation effectively reduces heating demand (while enhancing thermal comfort). This approach is cost-effective. Implementing fabric improvements would ensure long-term energy efficiency.
- Setting double glazing as a minimum requirement with incentives for triple glazing could balance cost and performance.
- Option 4 highlights that heat pumps without fabric upgrades yield modest savings due to ongoing heat loss with the building fabric. Given installation costs (~£13,000 excluding grants), pairing heat pumps with fabric upgrades maximises efficiency and cost-effectiveness. Encouraging this combination would enhance both energy and carbon savings.
- Encouraging a phased retrofit approach, starting with affordable fabric measures and integrating low-carbon heating later, provides the most balanced and cost-effective path to energy and carbon reductions. This staged approach spreads costs and ensures each step contributes meaningfully to energy performance.

Existing Terrace House Retrofits

	Option 1	Option 2.1	Option 2.2	Option 2.3	Option 3.1	Option 3.2	Option 4	Option 5
Space heating demand $kWh/m^2_{GIA}/yr$	169	**116**	158	152	**119**	**122**	169	**32**
Energy Use Intensity $kWh/m^2_{GIA}/yr$	252	**188**	239	231	**200**	**203**	80	**40**

Figure 7.1 – Summary of terrace baseline modelling results highlighting space heating demand and energy use intensity for individual retrofit measures and a full house retrofit

Energy modelling indicates limited improvements in total energy use and heating demand between Options 1 to 4, even with high-specification fabric and ventilation upgrades, as the extension represents a small proportion of the existing house. Fabric improvements alone add 1-3% to capital costs.

Electrification with air source heat pumps (Options 3 and 4) effectively reduces carbon emissions, particularly in outward extensions; however, due to high electricity costs, combining electrification with fabric upgrades is recommended to maximise both carbon and energy savings.

Outward extensions would benefit from a standalone air-to-air heat pump for efficient, independent heating. The upward and basement extensions require whole-house heat pump upgrades for consistent heating.

Outward extension

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Space heating demand $kWh/m^2_{GIA}/yr$	155	154	154	153	150	143	29
Energy Use Intensity $kWh/m^2_{GIA}/yr$	230	228	220	227	70	37	37

Figure 7.2 – Summary of space heating demand and energy use intensity results for the outward extension

Upward extension

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Space heating demand $kWh/m^2_{GIA}/yr$	107	105	105	98	93	85	20
Energy Use Intensity $kWh/m^2_{GIA}/yr$	173	172	165	162	133	52	34

Figure 7.3 – Summary of space heating demand and energy use intensity results for the upward extension

Basement extension

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Space heating demand $kWh/m^2_{GIA}/yr$	145	143	143	143	129	129	26
Energy Use Intensity $kWh/m^2_{GIA}/yr$	209	208	200	207	169	57	31

Figure 7.4 – Summary of space heating demand and energy use intensity results for the basement extension

Key

- Options that are fossil-fuel free
- Options with Solar PVs
- Ultra-low fabric to new extension only

Fabric upgrades alone are insufficient for significant energy and carbon reductions in converted flats. Full electrification with air-source heat pumps and insulation (Option 5) achieves the greatest carbon reduction, while a comprehensive whole-house retrofit (Option 6) maximises energy and emission savings, albeit with a 13% cost increase.

Ground floor units face higher energy bills, this suggests prioritising enhanced thermal performance measures for lower units to improve energy efficiency and occupant costs.

Recommended targets

Based on these results and the cost-effectiveness of various options, the following targets are recommended:

- **Space Heating Demand (SHD):** 108 kWh/m²/yr
- **Energy Use Intensity (EUI):** 71 kWh/m²/yr across all units.

Terrace to Flats

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Space heating demand $kWh/m^2_{GIA}/yr$	126	124	124	117	108	23
Energy Use Intensity $kWh/m^2_{GIA}/yr$	237	233	196	73	71	50

Figure 7.5 – Summary of space heating demand and energy use intensity results for the terrace to flats case

Key

– – Options that are fossil-fuel free

– – Options with Solar PVs

Upgrading an extension alone with ultra-low energy fabric, heat recovery ventilation, and an air source heat pump falls short of delivering significant reductions in operational energy and carbon for the whole building.

Extending an air source heat pump throughout the building (Option 5) provides substantial reductions in both carbon emissions and operational costs, although it increases capital costs by 21%.

The most comprehensive approach, a full retrofit encompassing fabric, ventilation, and low carbon heating (Option 6), maximises energy efficiency and minimises heating demand, achieving the highest energy and carbon savings, albeit with a 79% cost increase.

This demonstrates the need for financial incentives to make extensive retrofits viable and to support Camden's ambitious carbon reduction goals

Recommended targets

Based on these results and the cost-effectiveness of various options, the following targets are recommended:

- **Space Heating Demand:** 60 kWh/m²/yr
- **Energy Use Intensity (EUI):** 115 kWh/m²/yr

Large Office – Upward Extension

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Space heating demand $kWh/m^2_{GIA}/yr$	82	81	59	60	60	24
Energy Use Intensity $kWh/m^2_{GIA}/yr$	249	248	199	199	115	79

Figure 7.6 – Summary of space heating demand and energy use intensity results for the Large office upward extension case

Key

- – Options that are fossil-fuel free

- – Options with Solar PVs

An effective approach is implementing an electrical system (e.g. VRF, Variable Refrigerant Flow) across the entire building (Option 3), which achieves significant carbon reductions and offers energy efficient heating and cooling for variable office occupancy, all with a modest 0.6% cost uplift.

Retrofitting the entire building with air source heat pumps and high-performance fabric measures (Option 5) achieves substantial carbon savings.

Option 6, a comprehensive whole-building retrofit, maximizes energy and emissions reductions but increases capital costs by approximately 35% over the baseline. This underscores the effectiveness of extensive upgrades but also highlights the need for financial support to make these measures viable.

Recommended targets

Based on these results and the cost-effectiveness of various options, the following targets are recommended:

- **Space Heating Demand:** 59 kWh/m²/yr
- **Energy Use Intensity (EUI):** 94 kWh/m²/yr

Office – Demolition & Rebuild

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Space heating demand $kWh/m^2_{GIA}/yr$	66	65	16	59	59	15
Energy Use Intensity $kWh/m^2_{GIA}/yr$	202	201	98	172	94	77

Figure 7.7 – Summary of space heating demand and energy use intensity results for Large Office demolition and rebuild with upward and outward extensions

Key

– – Options that are fossil-fuel free

– – Options with Solar PVs

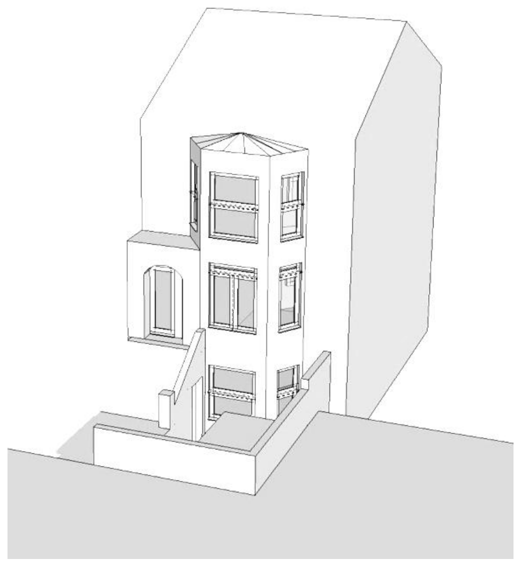
8.0

Appendix: assumptions and results

This section outlines the assumptions and the results from energy and cost modelling

A.1 Terrace Baseline

This section outlines the modelling assumptions for the Baseline retrofit scenarios



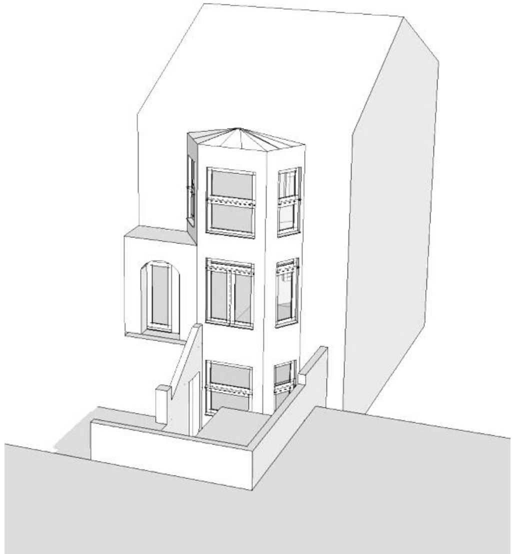
Terrace Baseline | Assumptions

Changes highlighted in pink and ***bold***

	Option 1	Option 2.1	Option 2.2	Option 2.3	Option 3.1	Option 3.2	Option 4	Option 5
Purpose	*Existing Building*	*Wall Insulation*	*Floor Insulation*	*Roof Insulation*	*Double glazing and ventilation*	*Triple glazing and ventilation*	*Install Heat Pump*	*Whole house retrofit*
Average internal temperature	Calculate/20C	Calculate/20C	Calculate/20C	Calculate/20C	Calculate/20C	Calculate/20C	Calculate/20C	Calculate/20C
Floors (W/m^{2}K)	1.00	1.00	**0.10**	1.00	1.00	1.00	1.00	**0.10**
Walls (W/m^{2}K)	2.10	**0.30**	2.10	2.10	2.10	2.10	2.10	**0.30**
Dormer Walls (W/m^{2}K)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dormer Roof (W/m^{2}K)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Roof (W/m^{2}K)	0.45	0.45	0.45	**0.12**	0.45	0.45	0.45	**0.12**
Windows (W/m^{2}K)	5	5	5	5	**1.2**	**0.8**	5	**0.8**
	(single-glazed)	(single-glazed)	(single-glazed)	(single-glazed)	**(double-glazed)**	**(triple-glazed)**	(single-glazed)	**(triple-glazed)**
Rooflights (W/m^{2}K)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Doors (W/m^{2}K)	2.5	2.5	2.5	2.5	**1.00**	**1.00**	2.5	**1.00**
Thermal bridge allowance (kWh/m2/yr)	3	3	3	3	3	3	3	3
Air Permeability (ACH)	8	8	8	8	8	8	8	8
Ventilation	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	**80% HR. 2m duct 25mm insulation**	**80% HR. 2m duct 25mm insulation**	Natural ventilation with intermittent extract fans	**80% HR. 2m duct 25mm insulation**
	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	**0.40 ACH**	**0.40 ACH**	0.2 to 0.5ach	**0.40 ACH**
	SFP - 0.15 W/m3/h	SFP - 0.15 W/m3/h	SFP - 0.15 W/m3/h	SFP - 0.15 W/m3/h	**SFP - 0.45 Wh/m3**	**SFP - 0.45 Wh/m3**	SFP - 0.15 W/m3/h	**SFP - 0.45 Wh/m3**
Space Heating	Gas combi boiler	Gas combi boiler	Gas combi boiler	Gas combi boiler	Gas combi boiler	Gas combi boiler	**ASHP**	**ASHP**
	Radiators > 60°C	Radiators > 60°C	Radiators > 60°C	Radiators > 60°C	Radiators > 60°C	Radiators > 60°C	**Radiators < 35°C**	**Radiators < 35°C**
	-	-	-	-	-	-	**5kW?**	**5kW?**
	Efficiency - 80%	Efficiency - 80%	Efficiency - 80%	Efficiency - 80%	Efficiency - 80%	Efficiency - 80%	**COP - 3.5 to 4.0**	**COP - 3.5 to 4.0**
	Weather comp - No	Weather comp - No	Weather comp - No	Weather comp - No	Weather comp - No	Weather comp - No	**Weather comp - Yes**	**Weather comp - Yes**
Domestic Hot Water	None	None	None	None	None	None	**Hot water storage cylinder, 120mm insulation at 60°C**	**Hot water storage cylinder, 120mm insulation at 60°C**
	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	**25mm pipe insulation good**	**25mm pipe insulation good**
	None	None	None	None	None	None	**180L**	**180L**
Technology	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**Monocrystalline silicon**
PV installed peak kWp	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**3**

A.2 Terrace Extensions

This section outlines the modelling assumptions for the Terrace extension scenarios



Terrace Extensions | Assumptions

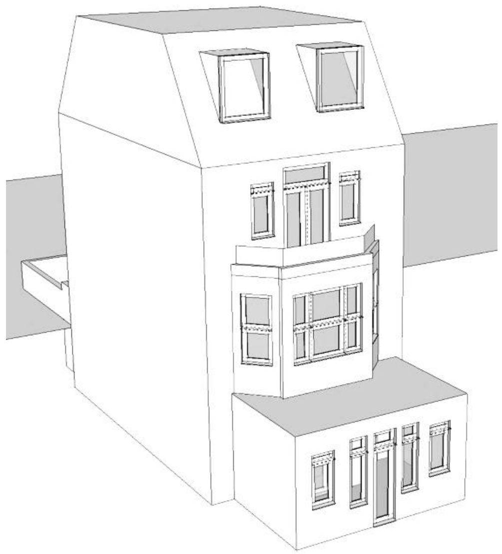
*Changes highlighted in pink and **bold***

**PVs added only to upward extensions*

	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6		Option 7	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*Low energy fabric + Direct electric (extension only)*		*Ultra low energy fabric (extension only)*		*Ultra-low energy fabric, MVHR and heat pump (extension only)*		*05 + heat pump (whole house)*		*Whole house retrofit*	
	Existing Building	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**
Floor (W/m^{2}K)	1.00	0.18	1.00	**0.10**	1.00	**0.10**	1.00	**0.08**	1.00	**0.08**	1.00	0.08	**0.25**	0.08
Walls (W/m^{2}K)	2.10	0.18	2.10	**0.15**	2.10	**0.15**	2.10	**0.13**	2.10	**0.13**	2.10	0.13	**0.30**	0.13
Walls with ground effect(W/m^{2}K)	2.10	0.18	2.10	**0.18**	2.10	**0.18**	2.10	**0.15**	2.10	**0.15**	**0.30**	0.15	**0.30**	0.15
Dormer Walls (W/m^{2}K)	N/A	0.30	N/A	**0.30**	N/A	**0.30**	N/A	**0.13**	N/A	**0.13**	N/A	0.13	N/A	0.13
Dormer Roof (W/m^{2}K)	N/A	0.25	N/A	**0.25**	N/A	**0.25**	N/A	**0.12**	N/A	**0.12**	N/A	0.12	N/A	0.12
Roof (W/m^{2}K)	0.45	0.15	0.45	**0.12**	0.45	**0.12**	0.45	**0.12**	0.45	**0.12**	0.50	0.12	0.50	0.12
Windows (W/m^{2}K)	5	1.4	5	**1.0**	5	**1.0**	5	**0.80**	5	**0.80**	5	0.80	**0.80**	0.80
	(single-glazed)	(double glazing)	(single-glazed)	**(triple-glazed)**	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	**(triple-glazed)**	(triple-glazed)
Rooflights (W/m2K)	3	2.2	3	**1.2**	3	1.2	3	1.2	3	1.2	2.2	1.2	1.2	1.2
Doors (W/m^{2}K)	2.5	1.4	2.5	**1.0**	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	**1.0**	1.0
Thermal bridge allowance	3	5	3	**4**	3	4	3	4	3	4	3	4	3	4
Air Permeability (ACH)	8	5	8	5	8	5	8	5	8	**<3**	5	<3	< 3	< 1
Ventilation	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	**80% HR. 2m duct 25mm insulation**	Natural ventilation with intermittent extract fans	80% HR. 2m duct 25 mm insulation	80% HR. 2m duct 25 mm insulation	80% HR. 2m duct 25 mm insulation
	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	**0.40 ACH**	0.2 to 0.5ach	0.40 ACH	0.40 ACH	0.40 ACH
	SFP - 0.15 W/m3/h	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	**SFP - 0.45 Wh/m3**	0.15 Wh/m3	SFP - 0.45 Wh/m3	SFP - 0.45 Wh/m3	SFP - 0.45 Wh/m3
Space Heating	Gas combi boiler	(same as house)	Gas combi boiler	(same as house)	Gas combi boiler	**Direct Electric**	Gas combi boiler	(same as house	Gas combi boiler	**Air-to-Air Heat Pump**	**ASHP**	(same as house)	ASHP	(same as house)
	Radiators > 60°C	(same as house)	Radiators > 60°C	(same as house)	Radiators > 60°C	**Electric heaters**	Radiators > 60°C	(same as house	Radiators > 60°C	**Cassette unit**	**Radiators < 35°C**	(same as house)	Radiators < 35°C	(same as house)
	-	(same as house)	-	(same as house)	-	(same as house)	-	(same as house	-	**2.6kW (9000btu)**	**8kW**	(same as house)	**5kW**	(same as house)
	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house	Efficiency - 80%	**COP - 3.5 to 4.0**	**COP - 3.5 to 4.0**	(same as house)	COP - 3.5 to 4.0	(same as house)
	Weather comp - No	(same as house)	Weather comp - No	(same as house)	Weather comp - No	(same as house)	Weather comp - No	(same as house	Weather comp - No	**Weather comp - Yes**	**Weather comp - Yes**	(same as house)	Weather comp - Yes	(same as house)
Domestic Hot Water	None	(same as house)	None	None	None	None	None	(same as house)	None	(same as house)	**Hot water storage cylinder, 120mm insulation at 60°C**	(same as house)	Hot water storage cylinder, 120mm insulation at 60°C	(same as house)
	10mm pipe insulation poor	(same as house)	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	(same as house)	10mm pipe insulation poor	**20mm pipe insulation medium**	**25mm pipe insulation good**	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good
	None	(same as house)	None	None	None	(same as house)	None	(same as house)	None	(same as house)	**180L**	(same as house)	180L	(same as house)
Technology*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**Monocrystalline silicon**	N/A	Monocrystalline silicon	N/A	Monocrystalline silicon
PV installed peak kWp*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**3**	N/A	3	N/A	3
System loss %*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**10 - 20%**	N/A	10 - 20%	N/A	10 - 20%

A.3 Terrace to Flats

This section outlines the modelling assumptions for the Terrace to Flats case



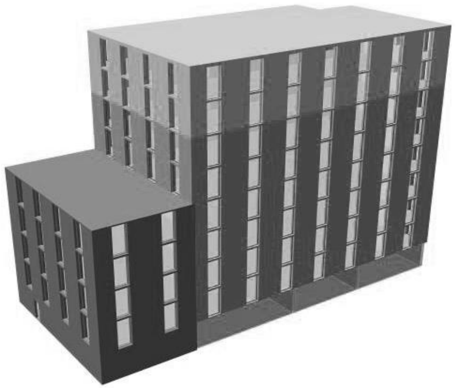
Terrace to flats | Assumptions

Changes highlighted in pink and ***bold***

	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*02 + Direct electric (extension only) & PV*		*Low energy fabric, MVHR (extension only) and heat pump (whole house)*		*04 + Ultra-low energy fabric (extension only)*		*Whole house retrofit*	
	Existing Building	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**	**Existing Building**	**Extension**
Walls (W/m^2K)	2.10	0.18	2.10	**0.15**	2.10	0.15	2.10	0.15	2.10	**0.13**	**0.30**	0.13
Dormer Walls (W/m^2K)	N/A	0.30	N/A	**0.30**	N/A	0.30	N/A	0.30	N/A	**0.13**	**0.16**	0.13
Dormer Roof (W/m^2K)	N/A	0.25	N/A	**0.25**	N/A	0.25	N/A	0.25	N/A	**0.12**	**0.16**	0.12
Roof (W/m^2K)	0.45	0.15	0.45	**0.12**	0.45	0.12	0.45	0.12	0.5	**0.12**	**0.16**	0.12
Windows (W/m^2K)	5	1.4	5	**1.0**	5	1.0	5	1.0	5	**0.80**	**0.80**	0.80
	(single-glazed)	(double glazing)	(single-glazed)	**(triple-glazed)**	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	(single-glazed)	(triple-glazed)	**(triple-glazed)**	(triple-glazed)
Rooflights (W/m2K)	3	2.2	3	**1.2**	3	1.2	3	1.2	2.2	1.2	1.2	1.2
Doors (W/m^2K)	2.5	1.4	2.5	**1.0**	2.5	1.0	2.5	1.0	2.5	1.0	**1.0**	1.0
Thermal bridge allowance	3	5	3	**4**	3	4	3	4	3	4	3	4
Air Permeability (ACH)	8	5	8	5	8	5	8	5	5	<3	**< 3**	**< 1**
Ventilation	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	**80% HR. 2m duct 25mm insulation**	Natural ventilation with intermittent extract fans	80% HR. 2m duct 25 mm insulation	**80% HR. 2m duct 25 mm insulation**	**(same as house)**
	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	0.2 to 0.5ach	**0.40 ACH**	0.2 to 0.5ach	0.40 ACH	**0.40 ACH**	**(same as house)**
	SFP - 0.15 W/m3/h	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	0.15 Wh/m3	**SFP - 0.45 Wh/m3**	0.15 Wh/m3	SFP - 0.45 Wh/m3	**SFP - 0.45 Wh/m3**	**(same as house)**
Space Heating	Gas combi boiler	(same as house)	Gas combi boiler	(same as house)	**Direct Electric**	(same as house)	**ASHP**	(same as house)	ASHP	(same as house)	ASHP	(same as house)
	Radiators > 60°C	(same as house)	Radiators > 60°C	(same as house)	**Electric heaters**	(same as house)	**Radiators < 35°C**	(same as house)	Radiators < 35°C	(same as house)	Radiators < 35°C	(same as house)
	-	(same as house)	-	(same as house)	-	-	**8kW**	(same as house)	8kW	(same as house)	**5kW**	**(same as house)**
	Efficiency - 80%	(same as house)	Efficiency - 80%	(same as house)	-	-	**COP - 3.5 to 4.0**	(same as house)	COP - 3.5 to 4.0	(same as house)	COP - 3.5 to 4.0	(same as house)
	Weather comp - No	(same as house)	Weather comp - No	(same as house)	Weather comp - No	(same as house)	**Weather comp - Yes**	(same as house)	Weather comp - Yes	(same as house)	Weather comp - Yes	(same as house)
Domestic Hot Water	None	(same as house)	None	None	None	(same as house)	**Hot water storage cylinder, 120mm insulation at 60°C**	(same as house)	Hot water storage cylinder, 120mm insulation at 60°C	(same as house)	Hot water storage cylinder, 120mm insulation at 60°C	(same as house)
	10mm pipe insulation poor	(same as house)	10mm pipe insulation poor	10mm pipe insulation poor	10mm pipe insulation poor	(same as house)	**25mm pipe insulation good**	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good	25mm pipe insulation good
	None	(same as house)	None	None	None	(same as house)	**180L**	(same as house)	180L	(same as house)	180L	(same as house)
Technology	N/A	N/A	N/A	N/A	N/A	**Monocrystalline silicon**	N/A	Monocrystalline silicon	N/A	Monocrystalline silicon	N/A	Monocrystalline silicon
PV installed peak kWp	N/A	N/A	N/A	N/A	N/A	**3**	N/A	3	N/A	3	N/A	3
System loss %	N/A	N/A	N/A	N/A	N/A	**10 - 20%**	N/A	10 - 20%	N/A	10 - 20%	N/A	10 - 20%

A.4 Large Office Extensions

This section outlines the modelling assumptions for the large office extension scenarios



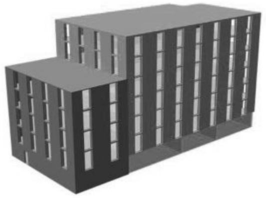
Large office baseline | Assumptions

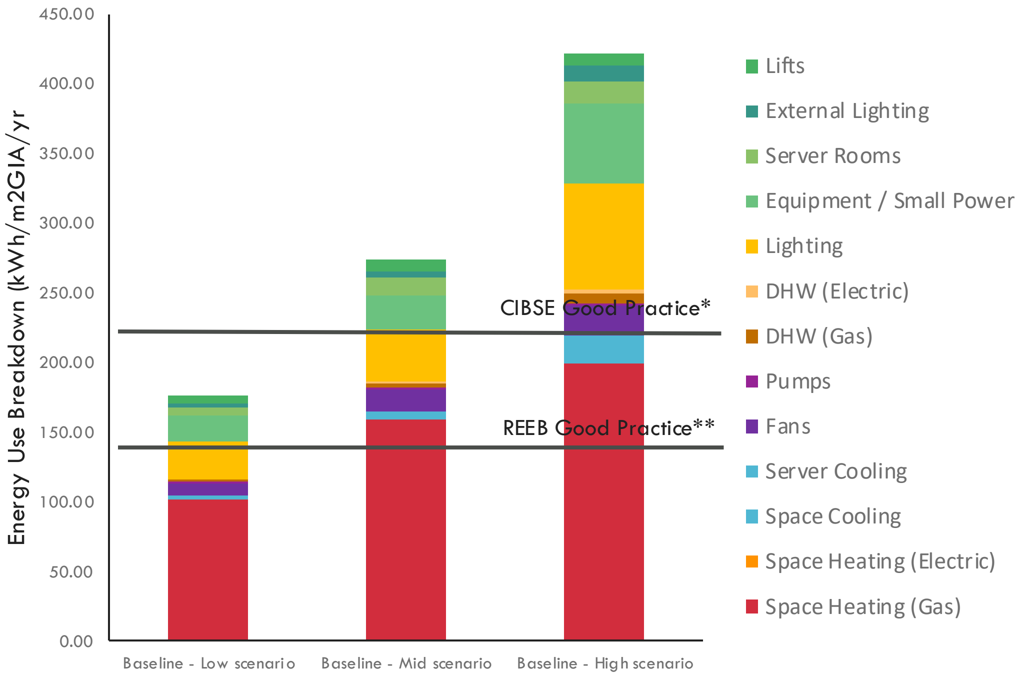
	Baseline building	
Purpose	Existing Building	Existing Extension
FABRIC & VENTILATION		
Floors (W/m^2K)	1.00	0.25
Walls (W/m^2K)	2.10	0.35
Roof (W/m^2K) - flat	1.40	0.25
Windows (W/m^2K) g-value	5.6 (single-glazed) 0.70	2.2 (single-glazed) 0.65
Curtain walling	5.6 (single-glazed)	N/A
External Doors (W/m^2K)	2.50	2.20
Air permeability (m^3/m^2h)	15 (0.45 ACH)	10 (0.3 ACH)
Ventilation system and design	Mechanical ventilation supply and extract to office. Extract only to WCs and shower rooms	
Ventilation system heat recovery efficiency	N/A	
Ventilation system SFP	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)	
Demand control ventilation	No	
BUILDING SERVICES		
Description of system	Gas boiler serving a heating system with flow and return temperature 70°C/50°C	
Heating emitters	LTHW 4-pipe Fan Coil Unit fed by Gas Boiler	
Hot water system	Direct electric hot water to hand wash basins. A 400L hot water store for the showers fed by gas boiler	
Heating and hot water seasonal efficieny	70% for heating and hot water, Distribution efficiency: 80%, Pump efficiency: 70%	
Cooling seasonal efficiency	SEER 3	
Internal lighting (W/m^2)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)	
Lighting control	No	
PHOTOVOLTAICS		
Description	No PVs assumed	
Photovoltaic Panels (kWp)	0.00	
Module Efficiency (%)	N/A	
Assumed area (Panel area)	N/A	
Tilt	N/A	
Shading	N/A	
Battery capacity (kWh)	N/A	

Large office | Assumptions of low, mid and high scenarios

	Range of specifications		
	Low case	**Mid case**	**High case**
Occupancy days / weekend working	No Saturday	As per main spec	With Sunday
Lighting levels (increased lux)	350 lux	450 lux	550 lux
Occupant density	20sqm / person	As per main spec	5sqm / person
Ventilation flow rate	16 l/s.person (8 equivalent)	10 l/s.person (as per main spec)	5 l/s.person (10 as equivalent)
Higher equipment /small power load	As per main spec	As per main spec	Spot load – as per main spec Equipment - 12 W/m2 Kettle - double
Increased server size / running hours	As per main spec	Double size	Double size (10% diversity)
Daily occupancy profile	Updated to remove Saturday	Increase to full capacity (1 person per 10m2 - no diversity)	Extend hours (from 7am until 10pm)-weekday Saturday same current weekday (max 40%) Sunday as current Saturday
Lighting profiles	Updated to remove Saturday	Increase peak to 90% in offices and 50% in other areas	Lights are left on 80% of the time. Increase peak to 90% in offices and 50% in other areas. Extend hours to reflect occupancy
Ventilation profiles	Updated to remove Saturday	4am to 9pm Mon to Sat	Full on 24/7
Equipment profiles	Updated to remove Saturday	Increase 9am to 5pm period by 40% (weekdays only)	Increase hours to reflect occupancy profile and increase peak to 50%
Heating / cooling thermostat profiles	Updated to remove Saturday	+ 1 degree heating, -1 cooling	+ 1.5 degrees heating, -1 cooling
Window openings?	As per main spec (no)	As per main spec (no)	Open by 1% during occupied hours
Lift usage / standby power	500 starts/day, 5 days per week	750 starts/day, 5.5 days per week	Extend days used per week. 51 weeks per year
DHW Demand	Reduced to reflect reduced occupancy (automatic)	As per main spec	Extend to reflect new occupancy profile / diversity
External lighting	Remove wall washers	10 wall washers and 10 sodium lamps on a timer	As current but high pressure left on over night

Large office baseline | Energy modelling results (low, mid, high scenarios)





** CIBSE Guide F Benchmarks*

*** Real Estate Environmental Benchmarks, Better Buildings Partnership*

Detailed energy use breakdown (kWh/m².yr)	Baseline – low case	Baseline – mid case	Baseline – high case
Space Heating (Gas)	88	86	63
Space Heating (Electric)			1
Space Cooling	3	4	1
Server Cooling	3	3	1
Fans	8	8	8
Pumps	1	1	1
DHW (Gas)	1	1	1
DHW (Electric)	1	1	1
Lighting	25	25	25
Equipment / Small Power	18	18	18
Server Rooms	5	5	5
External Lighting	3	3	3
Lifts	6	6	6

** CIBSE Guide F Benchmarks*

*** Real Estate Environmental Benchmarks, Better Buildings Partnership*

Large office extension | Assumptions

Changes highlighted in pink and ***bold***

	Option 1			Option 2			Option 3			Option 4			Option 5			Option 6		
Purpose	*Building regulations*			*Low energy fabric (extension only)*			*02 + VRF (extension only)*			*Ultra-low energy fabric, better MVHR and heat pump (extension only)*			*04 + heat pump (whole building)*			*Whole building retrofit*		
FABRIC & VENTILATION																		
	Existing Building	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**
Floors (W/m^{2}K)	1.00	0.25	0.18	1.00	0.25	**0.12**	1.00	0.25	0.12	1.00	0.25	**0.09**	1.00	0.25	0.09	**0.25**	0.25	0.09
Walls (W/m^{2}K)	2.10	0.35	0.26	2.10	0.35	**0.18**	2.10	0.35	0.18	2.10	0.35	**0.13**	2.10	0.35	0.13	**0.30**		0.13
Roof (W/m^{2}K) - flat	1.40	0.25	0.18	1.40	0.25	**0.13**	1.40	0.25	0.13	1.40	0.25	**0.10**	1.40	0.25	0.10	**0.18**		0.10
Windows (W/m^{2}K)	5.6 (single-glazed)	2.2 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1 (triple glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1 (triple glazed)	**1 (triple glazed)**		1 (triple glazed)
g-value	0.70	0.65	0.40	0.70	0.65	0.40	0.70	0.65	0.40	0.70	0.65	0.40	0.70	0.65	0.40	**0.40**		0.40
Curtain walling	5.6 (single-glazed)	2.2 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	2.2 (single-glazed)	**1.2 (triple glazed)**	5.6 (single-glazed)	2.2 (single-glazed)	1.2 (triple glazed)	**1.2 (triple glazed)**		1.2 (triple glazed)
External Doors (W/m^{2}K)	2.50	2.20	1.60	2.50	2.20	**1.50**	2.50	2.20	1.50	2.50	2.20	1.50	2.50	2.20	1.50	**1.50**		1.50
Air permeability (m^3/m^{2}h)	15 (0.45 ACH)	10 (0.3 ACH)	8 (0.22 ACH)	15 (0.45 ACH)	10 (0.3 ACH)	**5 (0.15 ACH)**	15 (0.45 ACH)	10 (0.3 ACH)	5 (0.15 ACH)	15 (0.45 ACH)	10 (0.3 ACH)	**1 (0.04 ACH)**	15 (0.45 ACH)	10 (0.3 ACH)	1 (0.04 ACH)	**5 (0.15 ACH)**		1 (0.04 ACH)
Ventilation system and design	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		**Best practice AHU**	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms		Best practice AHU	**Best practice AHU**		Best practice AHU
Ventilation system heat recovery efficiency	N/A		0.60	N/A		0.60	N/A		0.60	N/A		**0.85**	N/A		0.85	**0.85**		0.85
Ventilation system SFP	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)		1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)		1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)		**1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)**	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)		1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)		1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	**1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)**		1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)
Demand control ventilation	No		No	No		No	No		No	No		**Yes**	No		Yes	**Yes**		Yes

Large office extension | Assumptions

Changes highlighted in pink and ***bold***

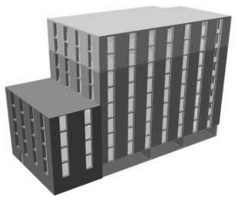
	Option 1			Option 2			Option 3			Option 4			Option 5			Option 6		
Purpose	*Building regulations*			*Low energy fabric (extension only)*			*02 + VRF (extension only)*			*Ultra-low energy fabric, better MVHR and heat pump (extension only)*			*04 + heat pump (whole building)*			*Whole building retrofit*		
BUILDING SERVICES																		
	Existing Building	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**
Description of system	Gas boiler serving a heating system with flow and return temperature 70○C/50○C		Same as main building	Gas boiler serving a heating system with flow and return temperature 70○C/50○C		Same as main building	Gas boiler serving a heating system with flow and return temperature 70○C/50○C		**VRF unit**	Gas boiler serving a heating system with flow and return temperature 70○C/50○C		**Commercial Air Source Heat Pump**	**Commercial Air Source Heat Pump**		Same as main building	Commercial Air Source Heat Pump		Same as main building
Heating emitters	LTHW 4-pipe Fan Coil Unit fed by Gas Boiler		Same as main building	LTHW 4-pipe Fan Coil Unit fed by Gas Boiler		Same as main building	LTHW 4-pipe Fan Coil Unit fed by Gas Boiler		**Fan Coil Unit fed by VRF**	LTHW 4-pipe Fan Coil Unit fed by Gas Boiler		**LTHW 4-pipe Fan Coil Unit fed by Heat Pump**	**LTHW 4-pipe Fan Coil Unit fed by Heat Pump**		Same as main building	LTHW 4-pipe Fan Coil Unit fed by Heat Pump		Same as main building
Hot water system	Direct electric hot water to hand wash basins A 400L hot water store for the showers fed by gas boiler		Direct electric hot water to hand wash basins	Direct electric hot water to hand wash basins A 400L hot water store for the showers fed by gas boiler		Direct electric hot water to hand wash basins	Direct electric hot water to hand wash basins A 400L hot water store for the showers fed by gas boiler		Direct electric hot water to hand wash basins	Direct electric hot water to hand wash basins A 400L hot water store for the showers fed by gas boiler		Direct electric hot water to hand wash basins	Direct hot water to hand wash basins **A 400L hot water store for the showers fed by heat pump**		Direct electric hot water to hand wash basins	Direct hot water to hand wash basins A 400L hot water store for the showers fed by heat pump		Direct electric hot water to hand wash basins
Heating and hot water seasonal efficieny	70% for heating and hot water Distribution efficiency: 80% Pump efficiency: 70%		95% for heating and hot water Distribution efficiency: 90% Pump efficiency: 90%	70% for heating and hot water Distribution efficiency: 80% Pump efficiency: 70%		95% for heating and hot water Distribution efficiency: 90% Pump efficiency: 90%	70% for heating and hot water Distribution efficiency: 80% Pump efficiency: 70%		**Scop 3.5 for heating**	70% for heating and hot water Distribution efficiency: 80% Pump efficiency: 70%		**Scop 3.2 for heating**	**Scop 3.2 for heating** **Scop 2.0 for hot water**		Scop 3.2 hor heating	Scop 3.2 for heating Scop 2.0 for hot water		Scop 3.2 hor heating
Cooling seasonal efficiency	SEER 3 Server DX SEER 4		Same as main building	SEER 3 Server DX SEER 4		Same as main building	SEER 3 Server DX SEER 4		**SEER 5** Server DX SEER 4	SEER 3 Server DX SEER 4		**SEER 5** Server DX SEER 4	**SEER 5** **Server DX SEER 4**		Same as main building	SEER 5 Server DX Seer 4		Same as main building
Internal lighting (W/m^2)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)		6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)		6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)		6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)		6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)		6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	**6.1 (offices_95W/lum.cirWatt @350 lux)**, 8 (ancillary spaces)		6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)
Lighting control	No		PIR Presence Detection + Daylight Dimming in Offices only	No		PIR Presence Detection + Daylight Dimming in Offices only	No		PIR Presence Detection + Daylight Dimming in Offices only	No		PIR Presence Detection + Daylight Dimming in Offices only	No		PIR Presence Detection + Daylight Dimming in Offices only	**PIR Presence Detection + Daylight Dimming in Offices only**		Same as main building

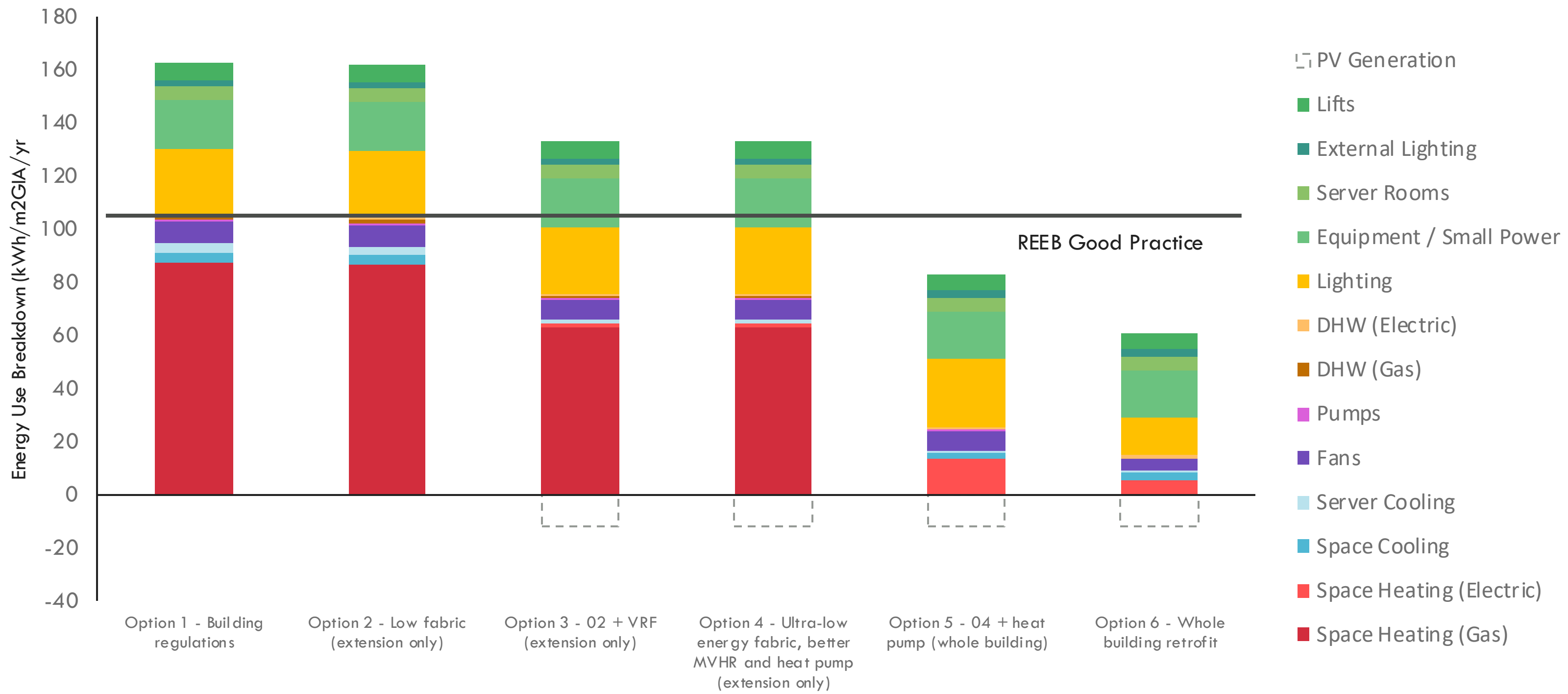
Large office extension | Assumptions

Changes highlighted in ***bold***

	Option 1			Option 2			Option 3			Option 4			Option 5			Option 6		
Purpose	*Building regulations*			*Low energy fabric (extension only)*			*02 + VRF (extension only)*			*Ultra-low energy fabric, better MVHR and heat pump (extension only)*			*04 + heat pump (whole building)*			*Whole building retrofit*		
PHOTOVOLTAICS																		
	Existing Building	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**	**Existing Building**	**Existing Extension**	**New Build Extension**
Description	No PVs assumed		No PVs assumed	No PVs assumed		No PVs assumed	No PVs assumed		**A standard practice for PVs assumed**	No PVs assumed		A standard practice for PVs assumed	No PVs assumed		A standard practice for PVs assumed	No PVs assumed		A standard practice for PVs assumed
Photovoltaic Panels (kWp)	0.00		0.00	0.00		0.00	0.00	0.00	**90**	0.00		90	0.00		90	0.00		90
Module Efficiency (%)	N/A		N/A	N/A		N/A	N/A	N/A	**20%**	N/A		20%	N/A		20%	N/A		20%
Assumed area (Panel area)	N/A		N/A	N/A		N/A	N/A	N/A	**420 m2 (70% of the building footprint area)**	N/A		420 m2 (70% of the building footprint area)	N/A		420 m2 (70% of the building footprint area)	N/A		420 m2 (70% of the building footprint area)
Tilt	N/A		N/A	N/A		N/A	N/A	N/A	**30**	N/A		30	N/A		30	N/A		30
Shading	N/A		N/A	N/A		N/A	N/A	N/A	**average (unknown)**	N/A		average (unknown)	N/A		average (unknown)	N/A		average (unknown)
Battery capacity (kWh)	N/A		N/A	N/A		N/A	N/A	N/A	**N/A**	N/A		N/A	N/A		N/A	N/A		N/A

Large office extension | Energy modelling results (low case)



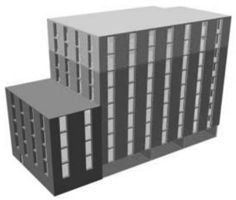


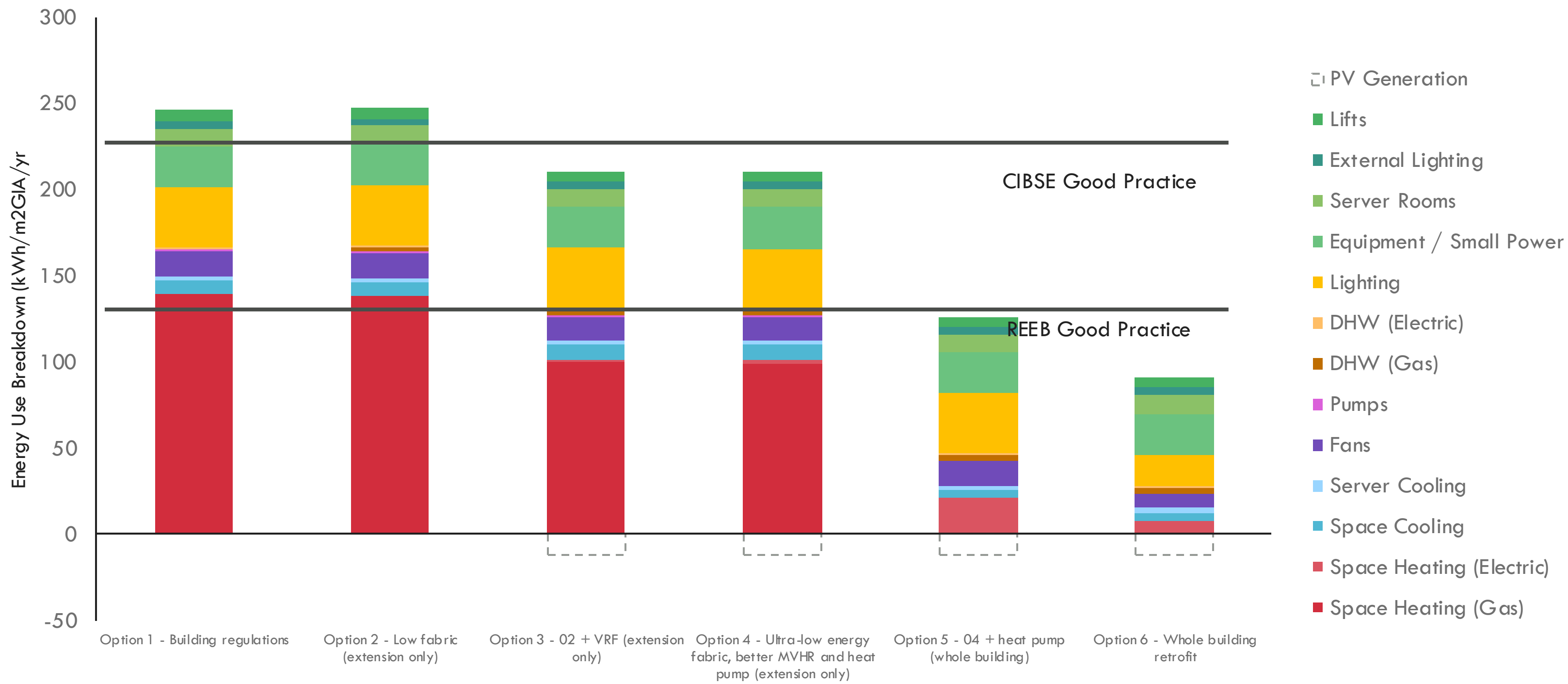
Detailed energy use breakdown (kWh/m².yr)	Option 1 - Building regulations	Option 2 - Low fabric (extension only)	Option 3 - 02 + VRF (extension only)	Option 4 - Ultra-low energy fabric, better MVHR and heat pump (extension only)	Option 5 - 04 + heat pump (whole building)	Option 6 - Whole building retrofit
Space Heating (Gas)	88	86	63	63		
Space Heating (Electric)			1	1	13	5
Space Cooling	3	4	1	1	2	3
Server Cooling	3	3	1	1	1	1
Fans	8	8	8	8	8	4
Pumps	1	1	1	1	0	0
DHW (Gas)	1	1	1	1		
DHW (Electric)	1	1	1	1	1	1
Lighting	25	25	25	25	25	14
Equipment / Small Power	18	18	18	18	18	18
Server Rooms	5	5	5	5	5	5
External Lighting	3	3	3	3	3	3
Lifts	6	6	6	6	6	6

** CIBSE Guide F Benchmarks*

*** Real Estate Environmental Benchmarks, Better Buildings Partnership*

Large office extension | Energy modelling results (mid case)



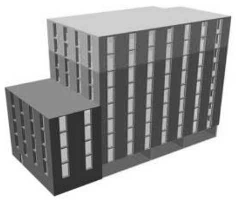


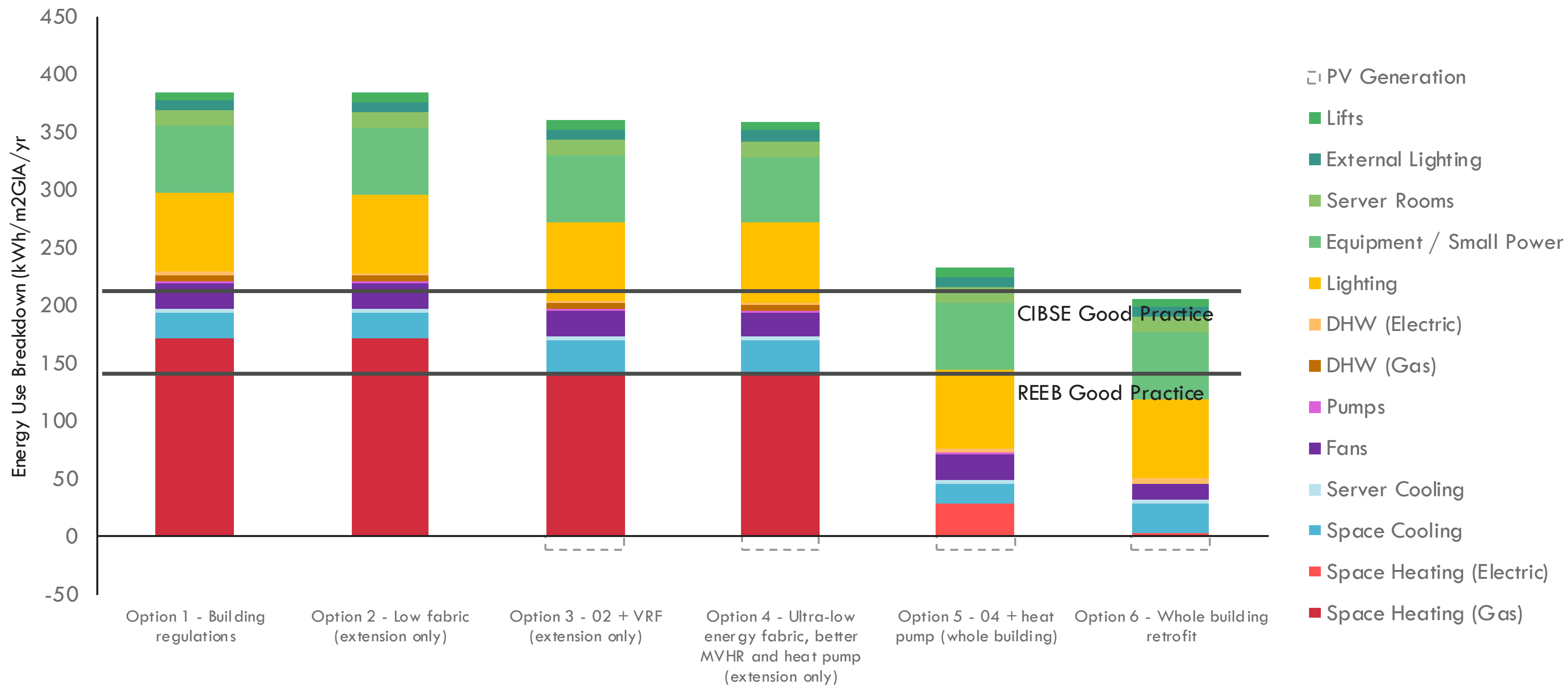
Detailed energy use breakdown (kWh/m².yr)	Option 1 - Building regulations	Option 2 - Low fabric (extension only)	Option 3 - 02 + VRF (extension only)	Option 4 - Ultra-low energy fabric, better MVHR and heat pump (extension only)	Option 5 - 04 + heat pump (whole building)	Option 6 - Whole building retrofit
Space Heating (Gas)	140	138	100	100		
Space Heating (Electric)			2	1	21	8
Space Cooling	7	8	9	9	5	5
Server Cooling	2	2	2	2	2	2
Fans	15	15	14	14	14	8
Pumps	1	1	1	1	1	0
DHW (Gas)		3	3	3	3	3
DHW (Electric)	1	1	1	1	1	1
Lighting	35	35	35	35	35	19
Equipment / Small Power	24	24	24	24	24	24
Server Rooms	10	10	10	10	10	10
External Lighting	4	4	4	4	4	4
Lifts	6	6	6	6	6	6

** CIBSE Guide F Benchmarks*

*** Real Estate Environmental Benchmarks, Better Buildings Partnership*

Large office extension | Energy modelling results (high case)





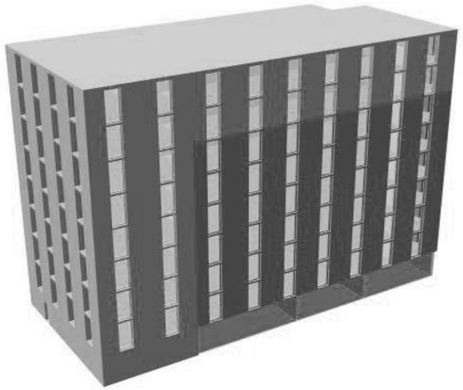
Detailed energy use breakdown (kWh/m².yr)	Option 1 - Building regulations	Option 2 - Low fabric (extension only)	Option 3 - 02 + VRF (extension only)	Option 4 - Ultra-low energy fabric, better MVHR and heat pump (extension only)	Option 5 - 04 + heat pump (whole building)	Option 6 - Whole building retrofit
Space Heating (Gas)	172	171	139	139		
Space Heating (Electric)			2	1	28	4
Space Cooling	22	22	29	28	18	24
Server Cooling	3	3	4	3	4	4
Fans	22	22	21	21	22	14
Pumps	2	2	1	2	1	1
DHW (Gas)	5	5	5	5		
DHW (Electric)	3	3	3	3	4	4
Lighting	68	68	68	68	68	68
Equipment / Small Power	58	58	58	58	58	58
Server Rooms	14	14	14	14	14	14
External Lighting	9	9	9	9	9	9
Lifts	7	7	7	7	7	7

** CIBSE Guide F Benchmarks*

*** Real Estate Environmental Benchmarks, Better Buildings Partnership*

A.5 Large office demolition & extension

This section outlines the modelling assumptions for the large office demolition and extension scenarios



Large office demolition & extension | Assumptions

Changes highlighted in ***bold***

	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*02 + VRF (whole building)*		*Ultra-low energy fabric, better MVHR and heat pump (extension only)*		*04 + heat pump (whole building)*		*Whole building retrofit*	
FABRIC & VENTILATION												
	Existing Building	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**
Floors (W/m^2K)	1.00	0.18	1.00	**0.12**	1.00	0.12	1.00	**0.09**	1.00	0.09	**0.25**	0.09
Walls (W/m^2K)	2.10	0.26	2.10	**0.18**	2.10	0.18	2.10	**0.13**	2.10	0.13	**0.30**	0.13
Roof (W/m^2K) - flat	1.40	0.18	1.40	**0.13**	1.40	0.13	1.40	**0.10**	1.40	0.10	**0.18**	0.10
Windows (W/m^2K)	5.6 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	**1 (triple glazed)**	5.6 (single-glazed)	1 (triple glazed)	**1 (triple glazed)**	1 (triple glazed)
g-value	0.70	0.40	0.70	0.40	0.70	0.40	0.70	0.40	0.70	0.40	**0.40**	0.40
Curtain walling	5.6 (single-glazed)	1.6 (double-glazed)	5.6 (single-glazed)	**1.4 (double-glazed)**	5.6 (single-glazed)	1.4 (double-glazed)	5.6 (single-glazed)	**1.2 (triple glazed)**	5.6 (single-glazed)	1.2 (triple glazed)	**1.2 (triple glazed)**	1.2 (triple glazed)
External Doors (W/m^2K)	2.50	1.60	2.50	**1.50**	2.50	1.50	2.50	1.50	2.50	1.50	**1.50**	1.50
Air permeability (m^3/m^2h)	15 (0.45 ACH)	8 (0.22 ACH)	15 (0.45 ACH)	**5 (0.15 ACH)**	15 (0.45 ACH)	5 (0.15 ACH)	15 (0.45 ACH)	**1 (0.04 ACH)**	15 (0.45 ACH)	1 (0.04 ACH)	**5 (0.15 ACH)**	1 (0.04 ACH)
Ventilation system and design	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Standard quality AHU	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	**Best practice AHU**	Mechanical ventilation supply and extract to office Extract only to WCs and shower rooms	Best practice AHU	**Best practice AHU**	Best practice AHU
Ventilation system heat recovery efficiency	N/A	0.60	N/A	0.60	N/A	0.60	N/A	**0.85**	N/A	0.85	**0.85**	0.85
Ventilation system SFP	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)	1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)	1.8 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s (supply and extract) 0.5 W/l.s (extract only) 0.6 W/l.s (FCU terminal units)	**1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)**	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)	1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	2.2 W/l.s supply and extract 0.5 W/l.s extract only 0.6 W/l.s (FCU terminal units)	1.2 W/l.s (supply and extract) 0.3 W/l.s (FCU terminal units)	**1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)**	1.2 W/l.s supply and extract 0.3 W/l.s (FCU terminal units)
Demand control ventilation	No	No	No	No	No	No	No	Yes	No	Yes	**Yes**	Yes

Large office demolition & extension | Assumptions

Changes highlighted in ***bold***

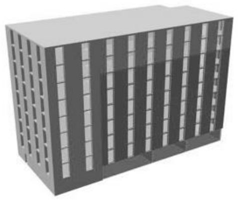
	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*02 + VRF (whole building)*		*Ultra-low energy fabric, better MVHR and heat pump (extension only)*		*04 + heat pump (whole building)*		*Whole building retrofit*	
BUILDING SERVICES												
	Existing Building	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**
Description of system	Gas boiler serving a heating system with flow and return temperature 70○C/50○C	Same as main building	Gas boiler serving a heating system with flow and return temperature 70○C/50○C	Same as main building	**VRF unit**	**VRF unit**	**Gas boiler serving a heating system with flow and return temperature 70○C/50○C**	**Commercial Air Source Heat Pump**	**Commercial Air Source Heat Pump**	Same as main building	Commercial Air Source Heat Pump	Same as main building
Heating emitters	LTHW 4-pipe Fan Coil Unit fed by Gas Boiler	Same as main building	LTHW 4-pipe Fan Coil Unit fed by Gas Boiler	Same as main building	**Fan Coil Unit fed by VRF**	**Fan Coil Unit fed by VRF**	**LTHW 4-pipe Fan Coil Unit fed by Gas Boiler**	**LTHW 4-pipe Fan Coil Unit fed by Heat Pump**	**LTHW 4-pipe Fan Coil Unit fed by Heat Pump**	Same as main building	LTHW 4-pipe Fan Coil Unit fed by Heat Pump	Same as main building
Hot water system	Direct electric hot water to hand wash basins A 400L hot water store for the showers fed by gas boiler	Direct electric hot water to hand wash basins	Direct electric hot water to hand wash basins A 400L hot water store for the showers fed by gas boiler	Direct electric hot water to hand wash basins	Direct electric hot water to hand wash basins **A 400L hot water store for the showers, fed by dedicated air source heat pump**	Direct electric hot water to hand wash basins	Direct electric hot water to hand wash basins **A 400L hot water store for the showers fed by gas boiler**	Direct electric hot water to hand wash basins	Direct hot water to hand wash basins **A 400L hot water store for the showers fed by heat pump**	Direct electric hot water to hand wash basins	Direct hot water to hand wash basins A 400L hot water store for the showers fed by heat pump	Direct electric hot water to hand wash basins
Heating and hot water seasonal efficieny	70% for heating and hot water Distribution efficiency: 80% Pump efficiency: 70%	95% for heating and hot water Distribution efficiency: 90% Pump efficiency: 90%	70% for heating and hot water Distribution efficiency: 80% Pump efficiency: 70%	95% for heating and hot water Distribution efficiency: 90% Pump efficiency: 90%	**Scop 3.5 for heating Scop 2.0 for hot water**	**Scop 3.5 for heating**	**70% for heating and hot water Distribution efficiency: 80% Pump efficiency: 70%**	**Scop 3.2 for heating**	**Scop 3.2 for heating Scop 2.0 for hot water**	Scop 3.2 hor heating	Scop 3.2 for heating Scop 2.0 for hot water	Scop 3.2 hor heating
Cooling seasonal efficiency	SEER 3 Server DX SEER 4	Same as main building	SEER 3 Server DX SEER 4	Same as main building	**SEER 5** Server DX SEER 4	**SEER 5** Server DX SEER 4	**SEER 3** Server DX SEER 4	SEER 5 Server DX SEER 4	**SEER 5** Server DX SEER 4	Same as main building	SEER 5 Server DX Seer 4	Same as main building
Internal lighting (W/m^2)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)	6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)	6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)	6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)	6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	12.8 (offices_45W/lum.cirWatt @350 lux), 8 (ancillary spaces)	6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)	**6.1 (offices_95W/lum.cirWatt @350 lux)**, 8 (ancillary spaces)	6.1 (offices_95 W/lum.cirWatt @350 lux), 8 (ancillary spaces)
Lighting control	No	PIR Presence Detection + Daylight Dimming in Offices only	No	PIR Presence Detection + Daylight Dimming in Offices only	No	PIR Presence Detection + Daylight Dimming in Offices only	No	PIR Presence Detection + Daylight Dimming in Offices only	No	PIR Presence Detection + Daylight Dimming in Offices only	**PIR Presence Detection + Daylight Dimming in Offices only**	Same as main building

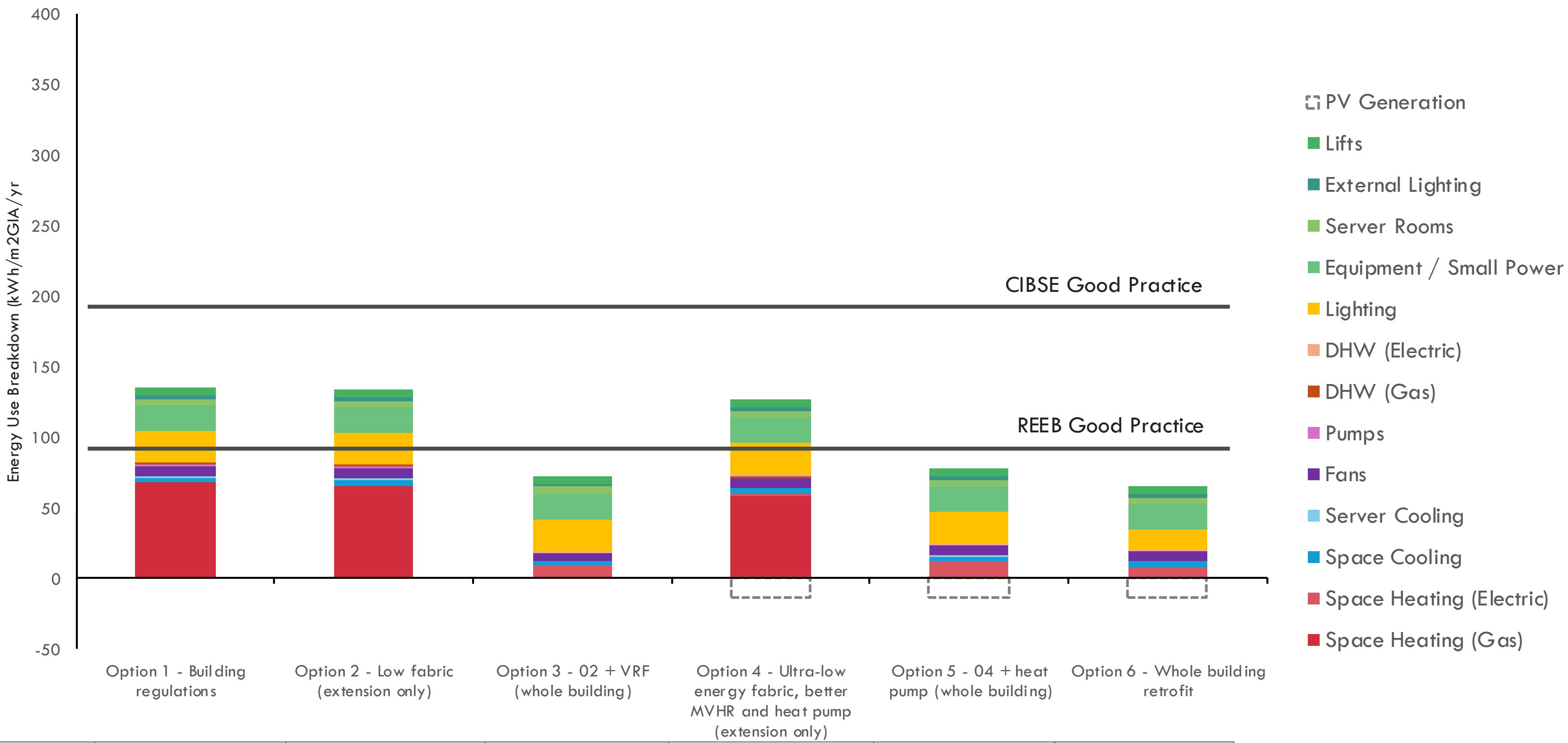
Large office demolition & extension | Assumptions

*Changes highlighted in **bold***

	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6	
Purpose	*Building regulations*		*Low energy fabric (extension only)*		*02 + VRF (whole building)*		*Ultra-low energy fabric, better MVHR and heat pump (extension only)*		*04 + heat pump (whole building)*		*Whole building retrofit*	
PHOTOVOLTAICS												
	Existing Building	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**	**Existing Building**	**New Build Extension**
Description	No PVs assumed	No PVs assumed	No PVs assumed	No PVs assumed	No PVs assumed	**A standard practice for PVs assumed**	No PVs assumed	A standard practice for PVs assumed	No PVs assumed	A standard practice for PVs assumed	No PVs assumed	A standard practice for PVs assumed
Photovoltaic Panels (kWp)	0.00	0.00	0.00	0.00	0.00	**119.7**	0.00	119.7	0.00	119.7	0.00	119.7
Module Efficiency (%)	N/A	N/A	N/A	N/A	N/A	**20%**	N/A	20%	N/A	20%	N/A	20%
Assumed area (Panel area)	N/A	N/A	N/A	N/A	N/A	**560m2 (70% of the building footprint area)**	N/A	560m2 (70% of the building footprint area)	N/A	560 m2 (70% of the building footprint area)	N/A	560 m2 (70% of the building footprint area)
Tilt	N/A	N/A	N/A	N/A	N/A	**30**	N/A	30	N/A	30	N/A	30
Shading	N/A	N/A	N/A	N/A	N/A	**average (unknown)**	N/A	average (unknown)	N/A	average (unknown)	N/A	average (unknown)
Battery capacity (kWh)	N/A	N/A	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A

Large office demolition & extension | Energy modelling results (low case)



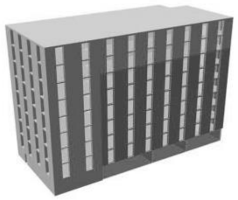


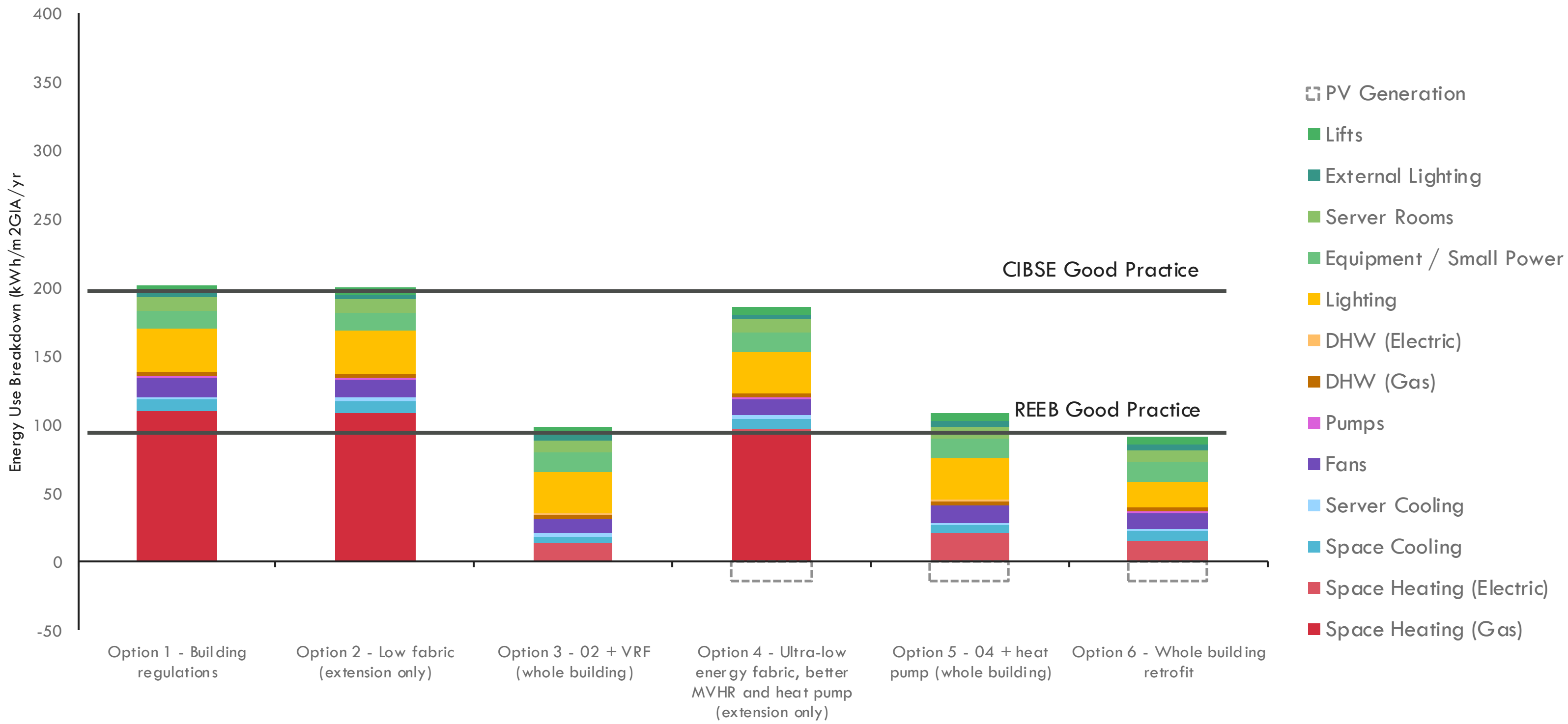
Detailed energy use breakdown (kWh/m².yr)	Option 1 - Building regulations	Option 2 - Low fabric (extension only)	Option 3 - 02 + VRF (whole building)	Option 4 - Ultra-low energy fabric, better MVHR and heat pump (extension only)	Option 5 - 04 + heat pump (whole building)	Option 6 - Whole building retrofit
Space Heating (Gas)	68	66		59		
Space Heating (Electric)			10	1	13	8
Space Cooling	4	4	2	3	3	4
Server Cooling	1	1	1	1	1	1
Fans	7	7	6	7	7	6
Pumps	1	1		1	1	0
DHW (Gas)	1	1		1		
DHW (Electric)	1	1	1	1	1	1
Lighting	22	22	22	22	22	14
Equipment / Small Power	19	19	19	19	19	19
Server Rooms	5	5	5	5	5	5
External Lighting	2	2	2	2	2	2
Lifts	6	6	6	6	6	6

** CIBSE Guide F Benchmarks*

*** Real Estate Environmental Benchmarks, Better Buildings Partnership*

Large office demolition & extension | Energy modelling results (mid case)



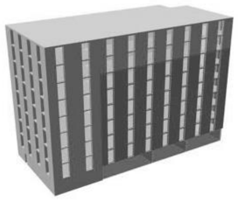


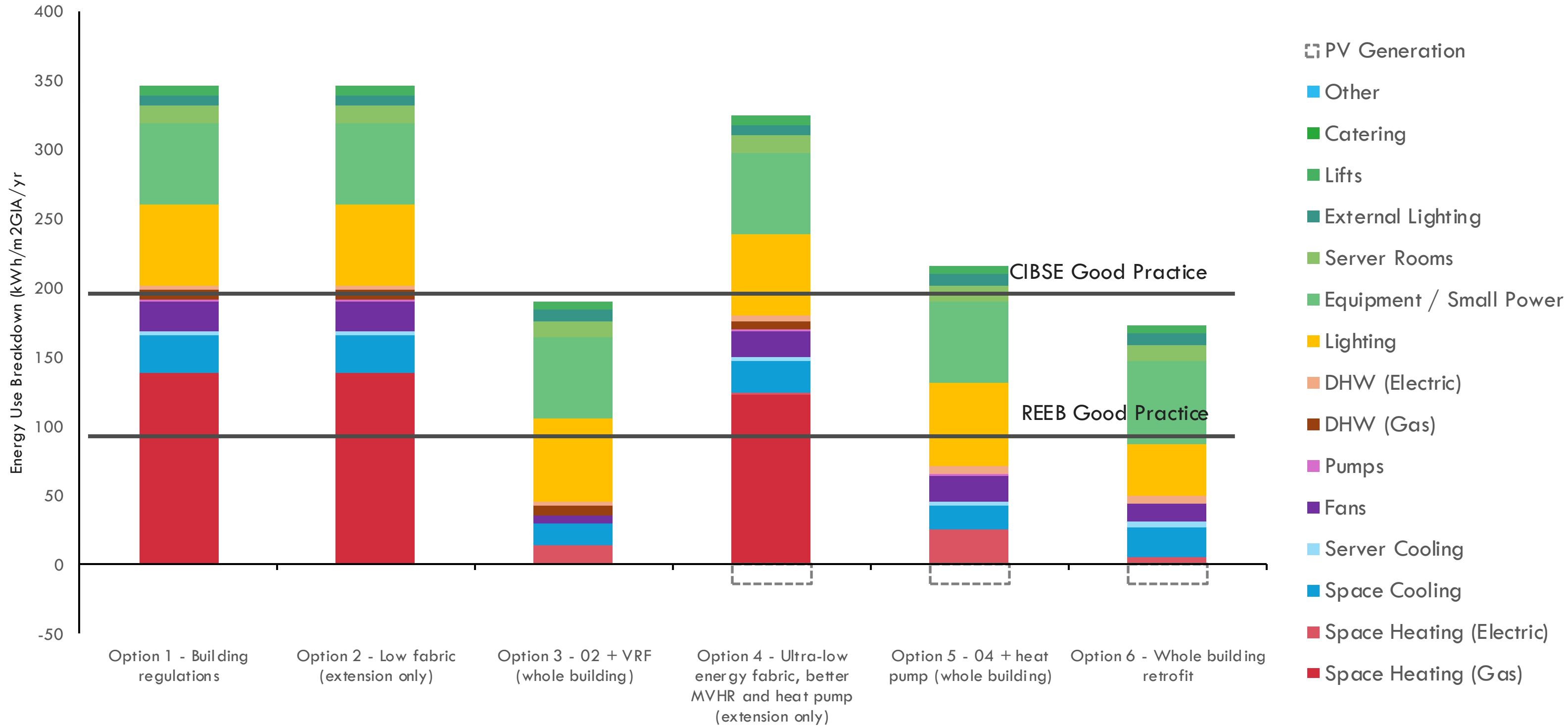
Detailed energy use breakdown (kWh/m².yr)	Option 1 - Building regulations	Option 2 - Low fabric (extension only)	Option 3 - 02 + VRF (whole building)	Option 4 - Ultra-low energy fabric, better MVHR and heat pump (extension only)	Option 5 - 04 + heat pump (whole building)	Option 6 - Whole building retrofit
Space Heating (Gas)	110	108		95		
Space Heating (Electric)			14	2	21	16
Space Cooling	8	9	4	7	6	6
Server Cooling	2	2	2	2	2	2
Fans	14	14	11	12	12	11
Pumps	1	1	0	1	1	1
DHW (Gas)	3	3	3	3	3	3
DHW (Electric)	1	1	1	1	1	1
Lighting	30	30	30	30	30	19
Equipment / Small Power	14	14	14	14	14	14
Server Rooms	9	9	9	9	9	9
External Lighting	4	4	4	4	4	4
Lifts	5	5	5	5	5	5

** CIBSE Guide F Benchmarks*

*** Real Estate Environmental Benchmarks, Better Buildings Partnership*

Large office demolition & extension | Energy modelling results (high case)





Detailed energy use breakdown (kWh/m².yr)	Option 1 - Building regulations	Option 2 - Low fabric (extension only)	Option 3 - 02 + VRF (whole building)	Option 4 - Ultra-low energy fabric, better MVHR and heat pump (extension only)	Option 5 - 04 + heat pump (whole building)	Option 6 - Whole building retrofit
Space Heating (Gas)	139	138		122		
Space Heating (Electric)			14	2	26	5
Space Cooling	27	28	15	22	17	22
Server Cooling	3	3	1	3	3	3
Fans	21	21	6	19	19	13
Pumps	2	2		2	1	1
DHW (Gas)	6	6	6	6		
DHW (Electric)	3	3	3	3	5	5
Lighting	59	59	59	59	59	38
Equipment / Small Power	59	59	59	59	59	59
Server Rooms	12	12	12	12	12	12
External Lighting	8	8	8	8	8	8
Lifts	6	6	6	6	6	6

** CIBSE Guide F Benchmarks*

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