The voice of our sustainable built environment

BUILDING THE CASE FOR NET ZERO: RETROFITTING OFFICE BUILDINGS

JANUARY 2024

UK Green Building Council
ukgbc.org

ADVANCING NET ZERO

ACKNOWLEDGEMENTS

UKGBC PROJECT TEAM

AUTHORS Anna Hollyman
Emily Dodkin

EDITORS Yetunde Abdul
Smith Mordak

COMMERCIAL RETROFIT TASK GROUP:

ARCADIS
Phil Clark
Georgia Hilling

ARUP
Michael Wadsworth

ASSURA
Paul Warrick

BAM
Joel Coakeley

BENNETTS ASSOCIATES
Peter Fisher

BIDWELLS
Dan Coston

BNP PARIBAS REAL ESTATE
Richard Kaye

BRITISH LAND
Nick Phillips

BRUNTWOOD
Alex Edwards
Etienne Humphries

CANARY WHARF GROUP
David Hodge

CARBONSHIFT
Matthew Hart

CBRE
Antonette Easwaranathan
Davion Cheng

CIVIC ENGINEERS
Simon Bennett

DELOITTE
Michelle Wang

GROSVENOR
Victoria Herring

HOARE LEA
Imogen Christodoulou
John Pirouet
Matthew Daniel

ISG
Mike Linehan

JLL
Niall Robertson

LLOYDS BANKING GROUP
Chinyelu Oranefo
Daniel Coakley

LOW CARBON ALLIANCE
Kieran Crowe

MITSUBISHI ELECTRIC UK
Chris Newman

MOTT MACDONALD
Bahareh Salehi

SAVILLS EARTH
Alexandros Chalkias

SCHNEIDER ELECTRIC
Brian O'Malley

SHAFTESBURY CAPITAL
Lisa Ilthurralde
Tom Attree

SQUIRE & PARTNERS
Bettina Brehler

THE CROWN ESTATE
Domenico Gabriele

TORRIDON
David Shaw

TURNER & TOWNSEND
Chris Joyce

TWIN EARTH
Jack Millard

VERCO
Dave Worthington

This study would not have been possible without the support of Programme and Project Partners, the Task Groups, reviewers, and contribution of significant resources to bring this study to life. UKGBC would like to sincerely thank all participants, alongside all involved stakeholders for their feedback, assistance and contributions over the course of the project. With special thanks to representatives from the following organisations who carried out the modelling and analysis: Arcadis, Arup, Bruntwood, Hoare Lea, Torridon, and Verco.

PROGRAMME PARTNERS:

PROJECT PARTNERS:

FOREWORD

We know from our broad membership and beyond, that averting climate breakdown and preparing for the climate change we've already locked in, is high on the agenda of office building users, owners, investors, and other stakeholders. This report is the result of a cross-industry collaboration that explored, and itself demonstrates how we need to work together more closely and more openly in order to achieve our collective aims.

We need to share data more transparently and effectively across different stakeholder groups. Office buildings are complex dynamic systems that include physical, technological, and human components. Lack of transparent data is preventing key feedback loops, for example occupants or facilities managers being able to see the impacts of their actions to empower them to change their behaviour and how they use the offices accordingly.

We need to plan now for deep, ambitious action. Average deep retrofit projects are reaching intermediate best practice targets, but only the deepest retrofit projects are reaching future net zero targets. Given that trigger points for deep retrofit may occur only every 10-15 years, retrofits being planned now need to aim for those more ambitious targets.

We need to think holistically, and long term. Building performance affects everyone, but sometimes in very different ways. As the way we're using offices has changed dramatically since the start of the pandemic, we've together learned that flexible working, the health and wellbeing of office users, and the autonomy and empowerment of colleagues to shift individual and collective behaviour is deeply cultural.

Retrofitting offices is a key component in decarbonising our society, becoming resilient to a changing climate, and improving the health and wellbeing of people and the wider ecosystem. Through radical collaboration, this is possible!

Smith Mordak
CHIEF EXECUTIVE
UKGBC

Commercial retrofits offer a significant opportunity for realising deep value. At FORE Partnership, we estimate there are around 6,500 office buildings above 20,000 sq ft in London alone in urgent need of retrofit to meet existing EPC regulations and hit London's ambitious net zero goals. Fixing them could save over £1 billion annually in electricity costs, and crucially as evidenced by study after study, drive up the investment value of these buildings by 15-20% through what has become a clear green premium.

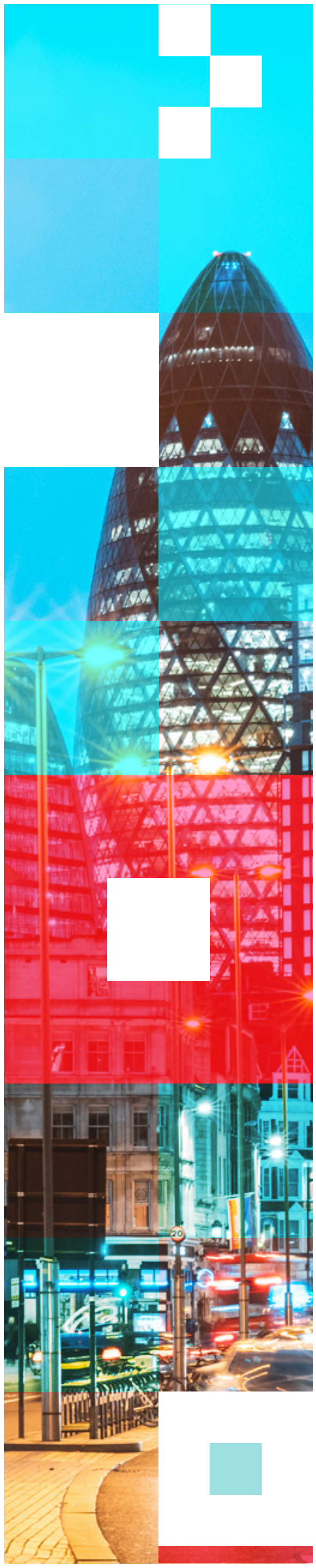
At around 1% to 1.5% of commercial property stock per year, the current pace of retrofit is nowhere near fast enough to hit the UK's 2050 goals, let alone our critical 2030 interim targets. If action is not taken now, increasing numbers of tired, old buildings will become unlettable and obsolete and the problem more entrenched. We must decisively accelerate the pace of retrofit.

This UKGBC report provides clear guidance on how to do just that, and builds a tangible evidence base to support investors, owners, occupiers, designers, and facilities management teams in developing their own business case for retrofit. Decarbonisation is a team sport, and we need to act collectively, now, to plan and implement retrofit strategies that simultaneously align with our business goals and close the gap towards net zero.

But the opportunity in retrofit goes beyond increasing return on investment and reducing carbon. Transforming outdated buildings creates environments that positively impact communities. Moving quickly to implement a broad retrofit strategy in our cities will improve health outcomes, build community resilience, and improve the most important metric – happiness. Retrofits also drive industry transformation and ensure a just transition by creating green jobs and upskilling workers into the industries of tomorrow. And imbedding technology in our retrofits helps to make our buildings work smarter, improves user experiences, and reduces costs.

Basil Demeroutis
MANAGING PARTNER
FORE PARTNERSHIP

CONTENTS



1 EXECUTIVE SUMMARY

1.1 PURPOSE

This report focuses on deepening understanding of how to retrofit large (>1000sqm) commercial office buildings towards net zero, the retrofit measures required, potential impacts, and associated costs. Building on UKGBC's foundational Key Considerations for Commercial Retrofits report, this report is aimed at investors, owners, and occupiers, and the consultants who work with them, and urges all stakeholders to prioritise the retrofit of existing assets, while ensuring they have long-term strategies in place that maximise co-benefits, and minimise unintended consequences.

1.2 METHODOLOGY

To produce this report, UKGBC convened a Task Group of industry experts with experience retrofitting their own office buildings or those of their clients. We drew live, anonymised, project data from the Task Group to determine common retrofit measures and outcomes. Live project data was supplemented by insights from the Task Group's experience to present a comprehensive summary of potential retrofit impacts and outcomes, both for each individual retrofit measure as well as each retrofit phase: optimisation, light retrofit and deep retrofit. Summaries are supplemented with a range of real-world case studies that provide practical examples of retrofit strategies, and include tangible outcomes across a range of metrics, e.g. operational energy performance, EPC rating, whole life carbon emissions, and projected returns on investment, as well as wider considerations including health, wellbeing and social value.

1.3 KEY FINDINGS

Overall the project concluded that significant reductions in operational energy use are possible through both optimisation and light retrofit (26% and 15% respectively or 37% combined), which generally include the most cost, and carbon-effective retrofit measures. Optimisation and light retrofit can be landlord or tenant-led, and success depends on effective collaboration between all stakeholders.

Deep retrofit is generally required to achieve significant cuts in operational energy use (60-65%), transition building systems away from fossil fuels, and meet best practice 2030-2035 energy performance targets for offices. We found the 'average' retrofit projects are not currently reaching best practice 2035-2050 targets, which the UK Net Zero Carbon Buildings Standard is anticipated to align with. Building fabric improvements are generally necessary to reach higher levels of performance, however these measures can have a relatively high embodied carbon impact.

Fabric upgrades should therefore be planned as part of significant refurbishment or repositioning strategies, and when building components are nearing their end of life, so that upgrades have both a marginal cost, and marginal whole life carbon impact.

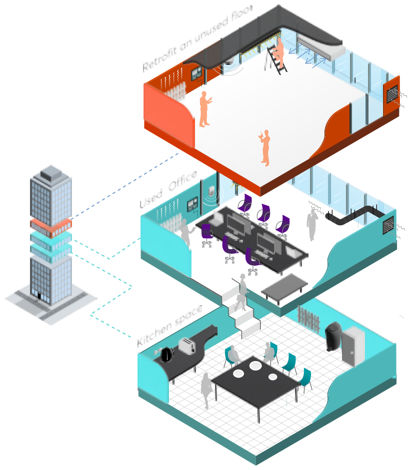
Consideration of both operational energy use and whole life carbon is essential to determine the most effective long-term decarbonisation strategies, so that we balance asset-level considerations with grid decarbonisation.

OPTIMISATION

26%

Average reduction in energy use intesity (EUI) from baseline through **Optimisation** alone.

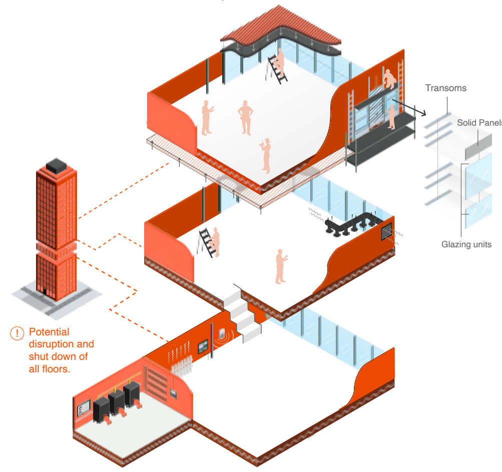
LIGHT RETROFIT



37%

Average reduction in energy use intesity (EUI) from baseline through **Optimisation** and **Light Retrofit**.

DEEP RETROFIT



60-65%

Average reduction in energy use intesity (EUI) from baseline through **Optimisation** and **Deep Retrofit**.

FIGURE 1:
Mean EUI reduction potential through each retrofit phase, from a median baseline EUI. For further detail see the Results section.

2 CALLS TO ACTION

Commercial buildings are currently not being retrofitted at the pace or scale necessary, risking the UK not meeting critical net zero milestones, and leaving many asset owners vulnerable to stranded assets [6] [7]. To accelerate retrofit and ensure retrofit strageties maximise long-term benefits, the following actions are needed:

RETROFIT NOW

Commercial office investors, owners, and occupiers must urgently plan and implement retrofit strategies that close the gap towards net zero.

Significant opportunities are being missed by those who do not have clear retrofit strategies in place. Firstly, through missing the easy wins – the low cost, low disruption measures that reduce energy consumption – and secondly, through missing key "trigger points" in lease and maintenance cycles, that facilitate smoother, more efficient retrofit.

GREATER TRANSPARENCY

All stakeholders must improve the quality and transparency of building performance data, to optimise in-use energy performance and recognise more holistic metrics.

A critical barrier to accelerating action is data transparency and accessibility. Sharing key performance and impact data at the same time as overall strategy ambitions should facilitate more open, frank, and constructive dialogue about progress and the challenges ahead. There are clear advantages for all stakeholders in reducing energy consumption and carbon emissions as far as possible. Stakeholders across the value chain will increasingly be required to report their climate impacts, and initiatives to drive down Scope 1, 2 and 3 emissions, meaning their roles and responsibilities are increasingly interdependent.

MINIMISE WHOLE LIFE CARBON

Whole life carbon assessments should be used to determine the most effective long-term decarbonisation strategies.

Whole life carbon assessments support evidence-based decision-making and illustrate the carbon savings of retrofit over new-build. UKGBC calls for mandatory measurement and reporting of Whole Life Carbon for new buildings and major refurbishments, initially for large buildings (>1000m2), followed by progressive limits on emissions over time. More details are set out in UKGBC's Embodied Carbon: Improving your Modelling and Reporting report. However, asset-level considerations must be balanced with the need to drive down operational energy demand across the built environment, which in turn facilitates grid decarbonisation.

INVEST IN LONG-TERM VALUE

All stakeholders should factor in long-term retrofit outcomes, and the wider benefits of retrofitting our built environment: social, economic and environmental.

There are huge opportunities to add value to existing buildings beyond reducing energy costs and net zero transition risks. Latent value can be unlocked by adding floor area, and through repositioning – or repurposing – offices to align more closely with tenant expectations or societal needs. Retrofit can also facilitate the integration of climate adaption and resilience strategies, nature-based solutions and biodiversity net gain, as well as improvements to occupant, and community health and wellbeing, and social value. More details are set out in the Wider Considerations of our Overarching Retrofit Strategy.

COLLABORATE AND SHARE LESSONS LEARNT

The scale of the retrofit challenge and the rate of decarbonisation needed requires a collaborative approach.

Unprecedented levels of collaboration will be essential to achieve, and maintain, the shifts in building performance needed to consistently drive down operational carbon emissions and meet net zero targets. We have the opportunity to leverage this radical collaboration, and the mutual understanding that comes with it, to move beyond zero-sum thinking and achieve the net zero, resilient and regenerative built environment that is necessary for us to thrive in the decades to come.

3 INTRODUCTION

3.1 WHAT DOES THIS GUIDANCE DELIVER?

There are growing regulatory and commercial risks associated with older, less energy-efficient buildings – particularly in the office market. As our awareness of the need to decarbonise our built environment grows, it is becoming clear that retrofitting existing buildings results in lower whole life carbon emissions than demolition and new build, whilst reducing the wider ecological impacts of construction waste and resource usage.

This report provides high-level guidance on the most appropriate retrofit measures, retrofit phases, the costs of implementation, and the likely impacts on both energy performance and whole life carbon emissions. It discusses the wider benefits and opportunities of retrofit and flags potential unintended consequences.

It also highlights the need for key stakeholders to establish an 'Overarching Retrofit Strategy' that sets out the most effective pathway to transition their office buildings, or portfolio of built assets, towards net zero over the short, medium and long term. It reframes retrofit as an iterative process that aligns with lease and maintenance cycles, rather than a standalone project. We have included an overview of the strategy guidance within this report, with further detail to be published in due course.

3.2 TARGET AUDIENCE

Building on our foundation setting guidance, Delivering Net Zero: Key Considerations for Commercial Retrofit, this report is aimed at:

- **Investors**
  Helping them build knowledge around the opportunities available through retrofitting less efficient assets towards net zero, as well as the potential costs and added value of doing so.
- **Owners/landlords**
  Advising them on the development of asset-level and portfolio-wide decarbonisation strategies, helping them build knowledge around the critical steps, and providing a high-level indication of carbon and cost impacts.
- **Occupiers/tenants**
  Supporting them in optimising the efficiency of existing tenancies and collaborating with landlords to facilitate mutually-beneficial retrofit strategies.
- **Design teams/consultants**
  Helping both to develop a clearer methodology when approaching retrofit and encouraging cross-industry collaboration.
- **Facilities management teams**
  Acknowledging their key role in developing the golden thread of information that deepens our understanding of how buildings operate and maximises the potential to optimise performance.

3.3 BACKGROUND

To mitigate the worst impacts of climate change, we need to rapidly decarbonise our existing buildings. The UK's existing non-domestic building stock is currently responsible for 23% of built environment operational carbon emissions [1]. It is estimated that 80% of today's buildings will still be in use in 2050, so the challenge of reducing operational carbon emissions will not be met through optimising new buildings alone [2]. The Carbon Risk Real Estate Monitor (CRREM) estimates that 87% of the improved performance needed for the European real estate sector to meet a 1.5°C aligned pathway, will need to come from existing buildings [3].

The data in Figure 1 is drawn from UKGBC's Net Zero Whole Life Carbon Roadmap (the Roadmap), which sets out the scale of operational carbon reductions required to meet the UK Government's legal commitment to reach net zero by 2050. A key aspect of this decarbonisation is the transition away from fossil fuels, which needs to go hand in hand with reductions in overall energy consumption to align with the UK's trajectory to a net zero economy. This trajectory is described for offices in UKGBC's Net zero carbon: energy performance targets for offices report which the UK Net Zero Carbon Buildings Standard is anticipated to align with.

Commercial offices in the UK account for circa 11% of energy consumption from non-domestic buildings [4]. However, apart from factories where industrial processes skew the building-related data, offices are currently the largest single consumers of electricity, at 15.5% of all non-domestic buildings [4]. Similarly, while only 7% of non-domestic buildings are over 1000 sqm in size, these large buildings account for over half of all total energy consumption [5]. Decarbonising large buildings will, therefore, have a more significant impact on total energy consumption per building retrofitted, and so they are the focus for this phase of work.

THE UK NET ZERO CARBON BUILDINGS STANDARD

The UK Net Zero Carbon Buildings Standard (The NZCB Standard) is a cross-industry initiative that aims to reach consensus around key principles that define net zero for different building typologies. Due to launch in 2024, it is expected to encompass operational energy performance, upfront embodied carbon, and whole life carbon limits. **Further details can be found here: www.nzcbuildings.co.uk**

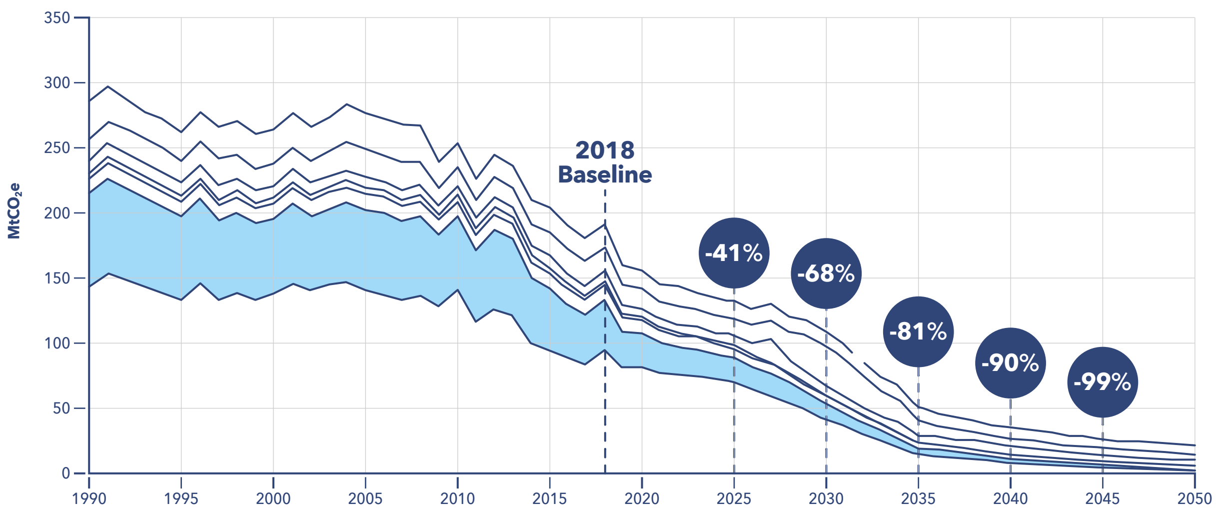
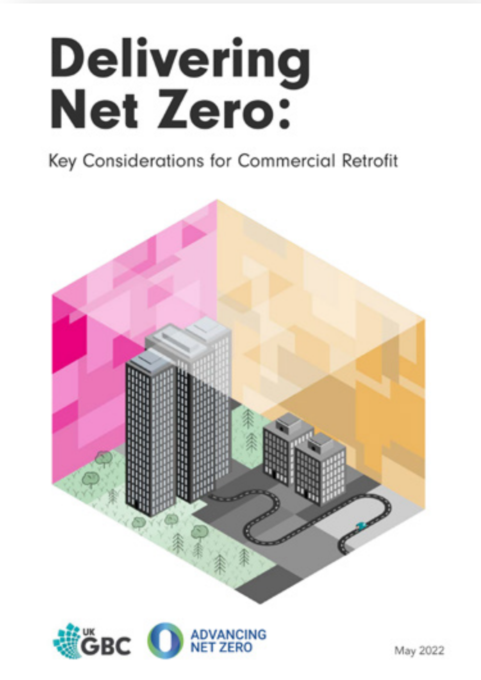


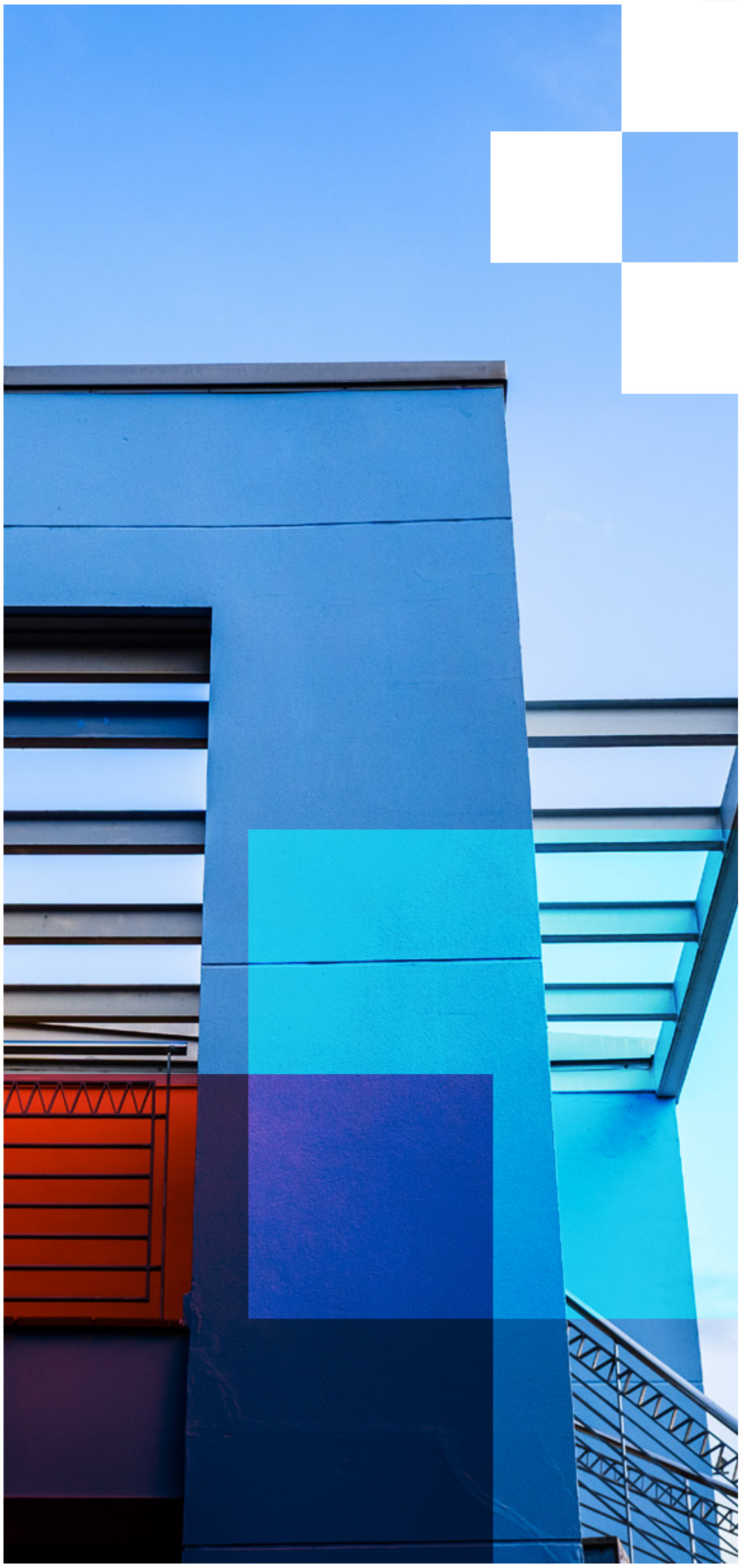
FIGURE 2:
Operational carbon emmissions from non-domestic buildings shown in blue, other categories unshaded.

3.4 KEY CONSIDERATIONS

In May 2022, UKGBC published a foundation setting guide – Delivering Net Zero: Key Considerations for Commercial Retrofit – which established a level of consistency by defining both light and deep retrofit, and clarifying the 10 key considerations for net zero carbon focused retrofit projects that support net zero pathways and goals, demonstrated through real-world case studies.

A key barrier identified by our previous guide is uncertainty around the practical implications of implementing net zero focused commercial retrofits. This report aims to address this barrier by sharing energy, carbon, and cost data from real-world retrofit projects, to raise awareness, build knowledge, and provide the increased confidence necessary to accelerate action.





3.5 POLICY DRIVERS

At the time of writing, there remains a high level of uncertainty around how current or future governments may act to drive down the carbon emissions from our existing commercial buildings, so as to meet the legal obligations set out by the Climate Change Act 2008. There are two outstanding Government consultations aimed at tightening energy efficiency standards for commercial offices the first through Energy Performance Certificate (EPC) ratings and the second through introducing performance-based ratings for large commercial [>1000sqm] buildings:

1. Non-domestic Private Rented Sector minimum energy efficiency standards: EPC B implementation, published 17 March 2021, closed 9 June 2021. UKGBC response here.
2. Introducing a performance-based policy framework in large commercial and industrial buildings, published 17 March 2021, closed 9 June 2021. UKGBC response here.

In response to existing and proposed legislation, most leading asset owners and landlords are already developing and implementing comprehensive strategies to both decarbonise their assets and transition each to an EPC rating of B or above. Nevertheless, the lack of clarity around how and when minimum energy efficiency standards (MEES) may kick in has led to hesitancy or delay among smaller, less strategic investors/owners. Savills' analysis of EPC data indicated that 77% of UK office stock is currently rated below EPC B, potentially at risk of stranding [8].

Furthermore, EPC ratings are only an indicator of potential performance and do not reflect actual energy use [9]. For policy drivers to be effective in reducing operational carbon emissions, we also need progress around introducing a performance-based policy framework as proposed by the Government, potentially similar to NABERS, the voluntary rating system now gaining traction in the UK.

NABERS UK

NABERS UK is a voluntary energy performance-based rating system now gaining traction in leading UK office markets. It is administered by BRE, following on from the work of the BBP Design for Performance initiative. NABERS UK was adapted from the Australian system, launched in 1999, which is considered to have been a highly effective tool in driving down the energy use in the prime office sector. NABERS provides a rating from one to six stars for offices, which helps building owners understand their building's performance versus other similar buildings, providing a benchmark for progress.

The emphasis on in-use performance and clear unambiguous benchmarks shifts the focus towards ensuring effective commissioning is carried out and facilities management (FM) teams proactively maintain efficiency levels, not just at handover, but for the long term so that ratings are maintained when verified on an annual basis. Existing buildings are eligible for a NABERS rating as soon as 12 months of a rating period can be completed. In these cases, the rating period can start as soon as one of the following conditions is met (whichever occurs first):

1. 75% of the office Net Internal Area (NIA) is occupied by tenants; or
2. It has been two years since the certificate of completion of any retrofit was issued.

3.6 MARKET DRIVERS

Since the first COVID-19 lockdowns in 2020, there have been significant shifts in workplace strategies, with organisations reacting in very different ways: from relinquishing all permanent office space, to enforcing office attendance for a minimum number of days per week. This has resulted in a spectrum of approaches to work patterns and occupancy rates.

The overall trend is clear: across Europe, offices are less occupied than pre-pandemic, with busy periods concentrated mid-week, and employees requiring clear incentives to regularly commute [10]. How office spaces are used has also shifted towards more collaborative working, alongside elevated technology requirements to support virtual calls, and hybrid meetings. The COVID-19 pandemic accelerated trends that were already emerging, however, there has been a material impact on how offices operate which has led the BCO to update their Guide to Specification earlier than anticipated [11]. This update also reflected a shift towards higher expectations around sustainability, performance ratings and net zero targets.

At a market scale, one key trend accelerated by COVID-19 is the flight to quality and, consequently, an increased polarisation of the market [12]. Premium grade A office space with clear sustainability and wellbeing credentials is highly sought after and seen as an effective way organisations can attract and retain talent, therefore at an asset level demanding higher yields and experiencing shorter void periods [13]. While conversely, the amount of unoccupied office space is currently at its highest level since 2014, up 65% in the last 3 years [14].

The drivers behind this trend will only become more defined as ambitions are raised; investors, building owners, and occupiers are all subject to growing scrutiny with regard to Environmental, Social and Governance (ESG) commitments – particularly with respect to their climate impacts from carbon emissions – and are increasingly pursuing a 'Retrofit first' strategy [15]. Similarly, recent increases in energy prices have raised awareness of future risks and shifted priorities towards greater energy efficiency.

FLIGHT TO QUALITY

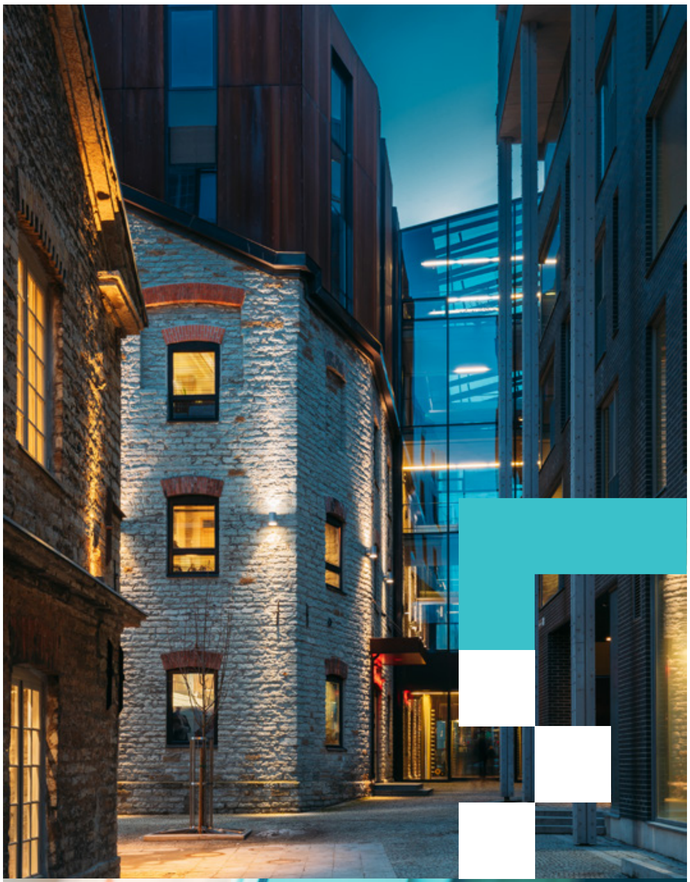
'Flight to quality' is a term derived from the financial markets and describes the movement of money from relatively risky investments to less risky ones, often during periods of high economic uncertainty [12]. In the context of commercial real estate, perceptions of quality have become increasingly linked to sustainability criteria, (i.e., BREEAM certification or EPC rating). This is due to a range of factors including the growing risk of stranded assets in the transition to net zero, and positive brand associations for companies that invest in sustainability and the wellbeing of their employees. This trend has been emerging for some time but has been accelerated by the COVID-19 pandemic lockdowns, alongside the widespread acceleration of hybrid working trends.

3.7 VALUE DRIVERS

A lack of clarity in policy direction, coupled with shifts in market trends, has led to a 'bubble' of carbon mispricing in valuations and a subsequent uncertainty around returns on investment [16]. Although the RICS Red Book Global Standards require the valuer to consider 'any sustainability and ESG factors that could affect the valuation', explicit reflection of sustainability in market or investment values is still limited in UK valuation practice, in part due to lack of clear, consistent metrics [17] [18]. Without more strategic forethought this 'value gap' could exacerbate existing societal issues, with increased risk of stranding assets among smaller, less informed, or resourceful owners/investors, or in regions that require more investment, not less.

The 'value' of our built environment is not limited to financial returns, however. The concept of social value is used to support real estate investors, owners, and occupiers in understanding the wider impact of their buildings and activities, and to establish a baseline against which to measure improvement. Social value is created when buildings, places and infrastructure support and enhance environmental, economic, and social wellbeing and in doing so improve quality of life [19]. Examples include upskilling to provide local green jobs, improving health and wellbeing, community integration, reducing waste, as well as mitigating and adapting to climate change.

To meet our built environment decarbonisation targets, we need to urgently address our existing buildings. Large commercial building owners and occupiers have the potential to lead the way in implementing retrofit strategies that reduce their carbon emissions while developing the knowledge and market conditions that enable smaller players to follow. Retrofit offers significant opportunities to add value to communities and society, which extend far wider than asset level considerations.



4 OVERARCHING RETROFIT STRATEGY

The **Overarching Retrofit Strategy** is intended to:

1. Support the process of setting out the immediate steps required to approach the retrofit of any large office building.
2. Encourage the long-term planning essential to avoid unintended consequences common to reactive or disparate retrofit interventions.
3. Ensure key opportunities are not missed.

Retrofitting buildings towards net zero is an iterative process likely to be made up of several distinct phases of light and deep retrofit, which improve and optimise building performance for the long term.

Further detail on the Overarching Retrofit Strategy, is to be published in due course.

OVERARCHING RETROFIT STRATEGY DIAGRAM

Prioritise action now, while planning for the future

TRIGGER POINTS

Critical opportunities to 'unlock' higher levels of performance, such as the end of tenant lease(s), vacant possession, standard maintenance and refurbishment cycles of building fabric or systems. Each trigger point should be scheduled into the Strategy, to set out when more significant, or disruptive retrofit projects can be carried out that are not feasible at other times. Trigger points can also be imposed externally, i.e., through MEES regulations.

Tracking & Optimisation

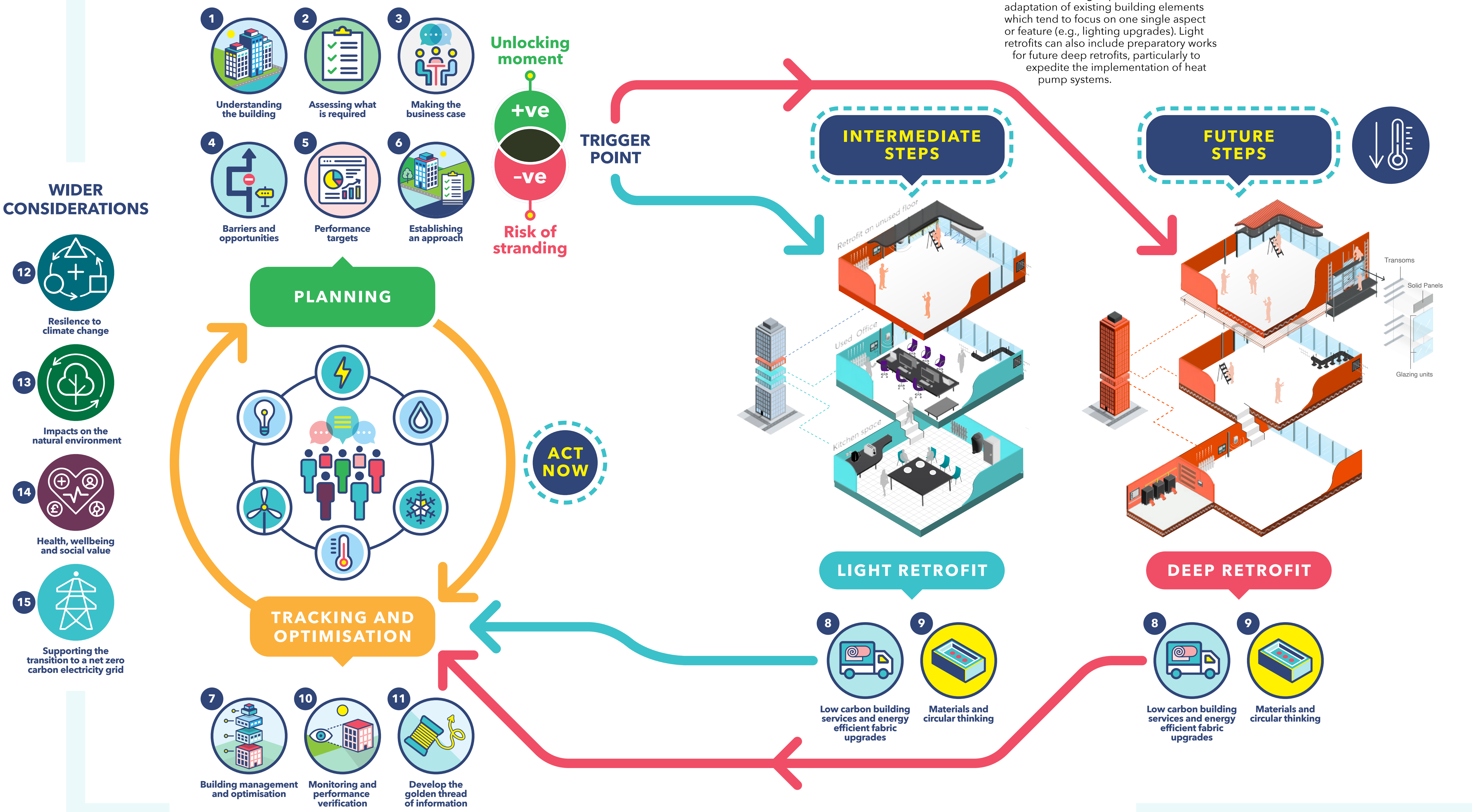
Performance optimisation is an iterative process where building controls and operational set points need to take into account, and be adjusted alongside, occupier behaviour. This iterative process needs to be repeated after each retrofit phase, to reoptimise and develop the golden thread of information that supports subsequent phases of retrofit.

Light Retrofit

Basic remodelling, replacement, or adaptation of existing building elements which tend to focus on one single aspect or feature (e.g., lighting upgrades). Light retrofits can also include preparatory works for future deep retrofits, particularly to expedite the implementation of heat pump systems.

Deep Retrofit

Significant works of size or scale that result in a fundamental change to the building structure and/or services. This can be represented as a collection of light retrofit enhancements, or individually disruptive measures such as major plant replacement. Deep retrofit is a key opportunity to reconsider the building as a whole system: fabric, HVAC, and energy generation and storage, etc. – an approach more challenging if works are carried out through a series of light retrofits.



KEY TO OVERARCHING RETROFIT STRATEGY DIAGRAM

KEY CONSIDERATIONS

The following 10 key consideration areas were set out within our Delivering Net Zero: Key Considerations for Commercial Retrofit report. Further detail and key areas of focus are provided within that report:

1 Understanding the building: Understanding the building is a key first step to help inform the most appropriate decision making on the project. to help inform the most appropriate decision making on the project.

2 Assessing what is required: An assessment appropriately tailored to the size and scale of the retrofit is essential to identify key areas of focus.

3 Making the business case: A balanced case must consider a broad range of drivers not only to illustrate the need for retrofit but also its potential benefits for owners and occupiers.

4 Barriers and opportunities: The potential barriers should be understood to identify ways to overcome them, and opportunities identified to best capitalise on them.

5 Performance targets: For retrofits where full building energy modelling and verification is planned, a clearly defined set of performance targets will both focus the decision-making process and provide clear benchmarks to track project performance.

6 Establish an approach: Establishing a standardised, scalable approach to multiple building or portfolio retrofits to support consistency and efficient implementation of low carbon measures.

7 Building management and optimisation: The existing building's operational optimisation is a critical first step in the retrofitting process.

8 Low carbon building services and energy efficient fabric upgrades: Understanding the condition of the existing building will help identify a hierarchy of low carbon options to pursue.

9 Materials and circular thinking: Reducing embodied carbon and promoting the circularity of construction materials and products is key to establishing a low carbon asset.

10 Monitoring and performance verification: To ensure low carbon benefits are realised, measurement, recording and evaluation of data should take place to verify the effectiveness of the retrofit measures.

DEVELOPING THE GOLDEN THREAD OF INFORMATION

An additional Key Consideration has been included, to emphasise the importance of recording and sharing building information, to facilitate optimisation and mitigate risk:

11 Developing the golden thread of information:
Developing accurate, up-to-date records of all data required to maintain and operate a built asset is key to successful optimisation and retrofit strategies.

WIDER CONSIDERATIONS

Wider Considerations relate to potential co-benefits, or win-wins, where efficiencies can be gained, and value added through integrating wider sustainability objectives:

12 Resilience to climate change:
Retrofit measures that simultaneously reduce emissions and protect occupants and assets from climate-related hazards, such as extreme heat and flooding, will ensure buildings are resilient to both transition and physical climate risks.

13 Impacts on the natural environment:
The building retrofit process provides an opportunity to incorporate nature, boost biodiversity and increase resilience to physical risks. The wider off-site, indirect, embodied impacts on nature should also be considered.

14 Health, wellbeing and social value:
Retrofit has the opportunity to not only improve the health and wellbeing of building occupants, but also improve the local environment, have a positive impact on communities, and add value to society.

15 Supporting the transition to a net zero carbon electricity grid:
Retrofit offers a significant opportunity to implement measures that enable buildings to become increasingly flexible and facilitate the active management of electricity demand, to support the transition towards a net zero carbon electricity system.

5 SCOPE AND METHODOLOGY

5.1 SCOPE

To identify retrofit strategies that most effectively close the gap towards net zero, UKGBC convened a broad industry task group and developed the following methodology to leverage their combined expertise and experience. The Task Group identified key metrics reflecting those expected to form part of the NZCB Standard as well as to respond to current policy drivers and market conditions. Detailed explanation of how these metrics were established can be found in the Appendices.

- **Whole building Energy Use Intensity (EUI)**
  Operational energy performance targets based on UKGBC's Net Zero Carbon: Energy Performance Targets for Offices.
- **Relative embodied carbon impact**
  Upfront embodied carbon impact in relation to whole life carbon saving. A RAG rating (Red, Amber, Green) has been used to create a distinction and to guide more detailed analysis regarding the 'carbon payback' of individual measures. Red implies greater caution is required to make sure the upfront embodied carbon cost, does not outweigh the long-term carbon savings.
- **Impact on EPC Rating**
  An estimation of each measure's impact on building EPC score (**Low** = 0-5points, **Medium** = 5-15 points, **High** = 15+ points).

RELATIVE EMBODIED CARBON IMPACT AND CARBON PAYBACK

In carbon reduction initiatives or projects the term 'carbon payback period' refers to a methodology to estimate how long it will take to offset greenhouse gases (GHG) emitted as a result of its implementation (the upfront embodied carbon or "carbon cost"), through reducing the GHG emitted previously ("the carbon saving").

The term is often used in the context of retrofit projects to estimate whether the upfront embodied carbon of retrofit measures implemented at a building level 'payback' when considering how much they reduce operational energy use over the building's life. This estimation requires converting operational energy to operational carbon through use of a 'carbon factor', which generally assumes that the electricity grid decarbonises by 2035 as per government targets.

However, as described in the UKGBC Renewable Energy Procurement guidance, to support an electricity system led primarily by wind and solar, buildings need to reduce demand, maximise the deployment of onsite generation, and operate flexibly, by responding to the availability of renewable electricity. If demand is not reduced, more renewable energy will need to be deployed at a greater carbon cost to the grid. Similarly, if buildings do not operate flexibly, peak demand will remain high with knock-on impacts to grid generation and/or storage requirements. Peak demand is currently supplied through gas generation at a greater cost, raising the price of all electricity supplied.

There is an inherent interdependence between the built environment and a net zero electricity system, which cannot be captured through an asset-level carbon payback calculation that does not consider the carbon cost of future decarbonisation. A more nuanced approach is required, as explored by LETI, that factors in wider externalities [20].

5.2 METHODOLOGY

STEP 1

SELECT OFFICE RETROFIT EXAMPLES

Existing commercial buildings vary significantly in their fabric construction, mechanical and electrical services, and how they are occupied and operated. To get an overview of both the baselines and outcomes of typical office retrofit projects, we drew live project data from our Partners and Task Group, using a comprehensive Excel template to standardise the information provided.

STEP 2

IDENTIFY COMMON RETROFIT MEASURES

The Task Group identified the most common retrofit measures modelled or implemented as part of the project datasets received. Measures encompassed operational improvements, fabric upgrades, services upgrades, and or replacements, as well as the incorporation of renewable energy systems.

STEP 3

EVALUATE COST AND CARBON IMPACT

The modelled impacts of common retrofit measures were normalised and compared to evaluate the average (mean) and range of outcomes on EUI, and any correlation with building age. Embodied carbon, cost and EPC impacts were also evaluated where provided, and supplemented with data derived the Task Group's experience to provide more comprehensive datasets.

STEP 4

DEVELOP RETROFIT 'PATHWAYS' TOWARDS NET ZERO

We identified two potential pathways towards net zero broadly applicable to different building types. The pathways explored the EUI reductions that could be achieved through different retrofit phases: Optimisation, light retrofit and deep retrofit. Pathway results were based on the aggregated, mean impact of retrofit measures typically carried out within each retrofit phase, as compared with the median baseline EUI.

STEP 5

ANALYSIS

We analysed the relative carbon and cost impacts of each retrofit measure, to explore the most effective measures to reduce carbon emissions per £ spent.

MEASURED VS MODELLED ENERGY USE DATA

The impact of retrofit measures was drawn from a wide range of building models that office owners, occupiers and consultants had developed to estimate the EUI reduction on specific real-world buildings. It is acknowledged that there is often a performance gap between a building's modelled energy performance and its energy performance in use.

It was not feasible at this time to use real-world data, as:

1. There is little consistent pre- and post-retrofit in-use operational energy data available.
2. Due to the impacts of COVID-19 lockdowns and the subsequent shifts in working patterns, it is difficult to make meaningful comparisons between pre- and post-pandemic data.

For further detail on the Methodology, assumptions, and steps to ensure accuracy, please see **Appendix 2**.

6 RESULTS

6.1 IMPACT OF RETROFIT MEASURES

Table 1 (opposite) gives an overview of the impact of common retrofit measures as implemented in current projects.

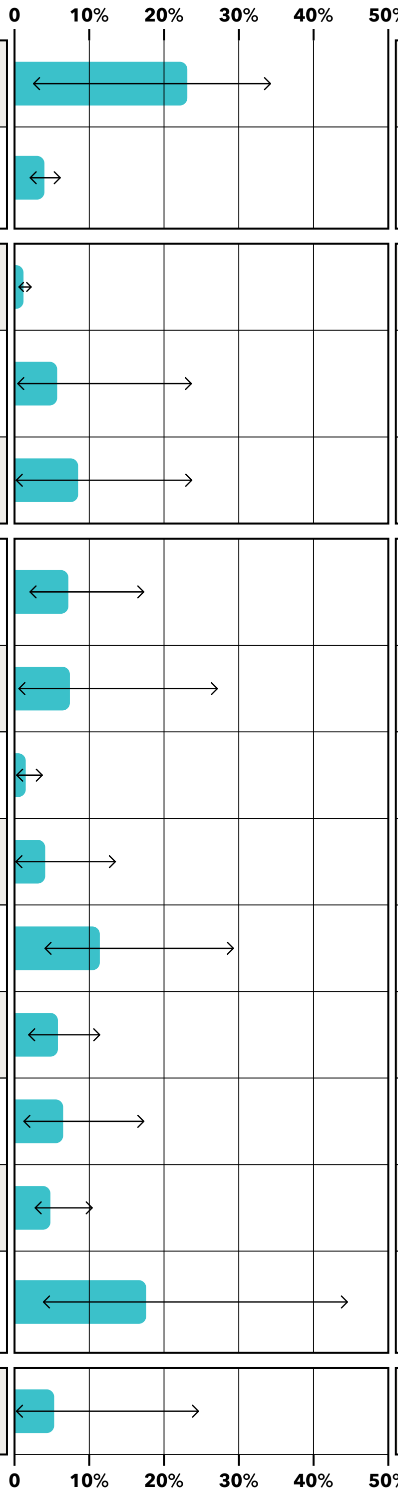
Measures are separated into the retrofit phases they are typically implemented as part of, however the order of implementation and how disruptive each measure may be, depends on each specific building context.

Average (mean) values are taken of each retrofit measure's EUI reduction from the respective project's baseline. The following impacts are illustrated:

1. Average (mean) reductions in EUI, shown as a percentage reduction from baseline.
2. Range of reductions in EUI, shown as a percentage reduction from baseline.
3. Cost range of implementation per square metre GIA, assuming measures are part of a wider project.
4. Relative emboodied carbon impact (Red, Amber, Green).
5. Estimated impact on EPC rating:
   - **Low** = 0-5,
   - **Medium** = 5-15,
   - **High** = 15+

   points added to existing EPC score.

For further detail on how each of these ratings were calculated and the associated assumptions and exclusions, refer to the **Appendices**.



Phase	Reference	Measure Type	Mean Impact on EUI	Relative Embodied Carbon Impact	EPC Impact	Cost £/m² GIA	Notes
Optimisation	1	Reduce Tenant Loads	-23.1%	Green	N/A	Varies	Dependent on tenant operations, moving to cloud servers can be most significant contributory.
Optimisation	2	Building Management System (BMS) Health Check/Upgrade	-4.0%	Green	Low	£1 - £3	Cost of replacement BMS £20-£50/sqm impacts dependent on scale of improvements possible.
Light Retrofit	3	Pump Motor Replacement	-1.2%	Green	Low	£2 - £5	-
Light Retrofit	4	Lighting Controls	-5.7%	Green	Med	£1 - £5	Lighting controls implemented at the same time as low energy lighting, can result in significant combined reductions in EUI.
Light Retrofit	5	Low Energy Lighting	-8.5%	Green	Med	£10 - £60	-
Deep Retrofit	6	Building Airtightness	-7.2%	Green	Med	£2 - £10	Some air tightness improvements can be carried out as light retrofit, however significant improvements require deep retrofit.
Deep Retrofit	7	Window Replacement	-7.4%	Amber	Low	£60 - £150	Improved air tightness is a co-benefit of window replacement. Higher results may incorporate the impact of air tightness.
Deep Retrofit	8	Roof Insulation	-1.5%	Red	Low	£10 - £50	Little whole building benefit as the positive impacts are limited to the top floor.
Deep Retrofit	9	Wall Insulation	-4.1%	Red	Low-Med	£20 - £60	Wide variation in EUI reduction reflects the significant differences in material specification and their application.
Deep Retrofit	10	Façade Replacement	-11.4%	Red	Low	£640*	Wide variation in EUI reduction reflects the significant differences in available technologies and their application.
Deep Retrofit	11	Mechanical Ventilation and Heat Recovery (MVHR)	-5.8%	Green	Low	£40 - £100	-
Deep Retrofit	12	CO_2 Ventilation Control	-6.5%	Green	Low	£2 - £10	-
Deep Retrofit	13	Air Source Heat Pump (ASHP) for Domestic Hot Water (DHW	-4.8%	Amber	Low	£10 - £20	-
Deep Retrofit	14	Decarbonisation of Heat (e.g. ASHP)	-17.6%	Green	High	£50 - £220	Wide variation in EUI reduction reflects different technologies available and the degree to which they can be implemented.
Renewables	15	Solar PV	-5.3%	Green	Low	£3 - £30	Dependent on roof area available.

TABLE 1: The Impact of common retrofit measures, as implemented in current projects.

*Refers to £/m² GIFA, rather than GIA.

Key to Graph

- **Average** reduction in EUI
- **Lowest** reduction in EUI
- **Highest** reduction in EUI

Relative Embodied Carbon Impact

upfront embodied carbon is...

Red	>100%
Amber	50-100%
Green	<50%

...of whole-life operational carbon savings

EPC Impact Scores

Low	0-5
Medium	5-15
High	15+

...added to baseline EPC rating scores.

DEFINING OPTIMISATION

How building users operate their buildings plays a critical, but often poorly understood and overlooked role in discussions around retrofit – buildings don't use energy, people do. Tracking how people are using energy, and optimising its effective use is essential prior to the consideration of any fabric or building services upgrades. Optimisation inititives are broadly divided into the two following measures:

1. Reduce Tenant Loads **2.** BMS Upgrade/Health check

REDUCE TENANT LOADS

The following are key initiatives that can support understanding and Landlord/Tenant collaboration to optimise energy performance.

Sub-metering
Sub-metering tenant spaces using Automatic Meter Readings (AMR)s is essential for occupants to understand their respective energy use, and each party being aware of, and responsible for reducing their own consumption.

Office equipment can account for 15% of office energy use and significant savings can be made by implementing simple good practice measures like turning equipment off when not in use, regular maintenance, and upgrading to more energy efficient appliances and equipment when appropriate.

Off-site cloud computing
Moving towards off-site cloud computing with limited with on-site server room usage can have the most significant impact on reducing tenant loads. It is acknowledged that relocating servers off-site effectively shifts the associated energy and carbon emissions from buildings from Scope 2 emissions (direct energy usage) to Scope 3 (supply/value chain). However as discussed in our Building the Case for Net Zero Buildings report, studies have found that cloud-based operations are significantly more efficient than local server rooms, due to increased IT operational efficiency, IT equipment efficiency, and data centre infrastructure efficiency.

REDUCE TENANT LOADS (CONTINUED)

Green leases expand traditional leases with legally binding clauses that enable owners and occupiers of commercial buildings to work together to reduce the environmental impact of their buildings. The Better Buildings Partnership Green Lease Toolkit aims to guide owners and occupiers to come to suitable agreements for their circumstances, based on best practice recommendations. It offers pre-established green lease clauses that can be included in new leases.

BMS UPGRADE / HEALTH CHECK

Building Management Systems (BMS) are computer-based systems used to monitor and control building services such as lighting, heating, ventilation and air conditioning (HVAC) and shading devices, as well as power distribution, and energy consumption. They can help Building and Facilities Managers understand how buildings are operating and to optimise their performance.

However BMS can be complex and their effectiveness can easily be affected by buildings not being occupied as assumed, poor maintenance or commissioning, or Building/Facilities Managers not fully leveraging their potential to optimise energy efficiency. Adjustments to their settings can result in significant savings, for example:

- Revise timeclocks to better match actual occupation;
- Implement optimised start / stop;
- Address faulty, poorly located & erroneous sensors;
- Reduce simultaneous heating & cooling between air handling units & terminal units;
- Improve heating & cooling system sequencing.

6.2 RETROFIT PATHWAYS TOWARDS NET ZERO

The Overarching Retrofit Strategy distinguishes between three phases of retrofit: optimisation, light retrofit, and deep retrofit. To illustrate the level of EUI reduction that could be achieved through each phase of retrofit, we developed ‘pathways’ towards net zero. Not all retrofit measures modelled could be implemented as part of the same deep retrofit strategy, so Pathway 1 and Pathway 2 differentiate between two divergent combinations of retrofit measures that could be implemented in different types of buildings.

The main differentiator between the two pathways is that Pathway 1 includes wall insulation and window replacement, while Pathway 2 comprises façade replacement. Pathway 2 also includes several measures (MHVR and CO2 ventilation control) more commonly associated with more complex building systems.

The pathways were determined using the average (median) EUI of project datasets: 172 kWh/m2 as a baseline, then aggregating the mean percentage impact of each retrofit measure, to estimate the overall EUI reduction that could be achieved through each phase. Both pathways comprise the same retrofit measures at optimisation and light retrofit but diverge at deep retrofit.

We note that several interventions may be considered light retrofit in certain circumstances yet considered deep retrofit in others. Similarly, the term medium retrofit is also commonly used in industry so there is no absolute distinction between each phase. For clarity we have listed the retrofit measures assumed to be implemented as part of each phase in Table 2 opposite.

The pathways do not consider the aggregated embodied carbon impacts of retrofit measures, however recent research by CRREM found the ‘carbon payback’ of deep retrofits of commercial buildings to be under 8 years, even when taking grid decarbonisation into account, while light retrofit payback periods could be below 3 years [12].

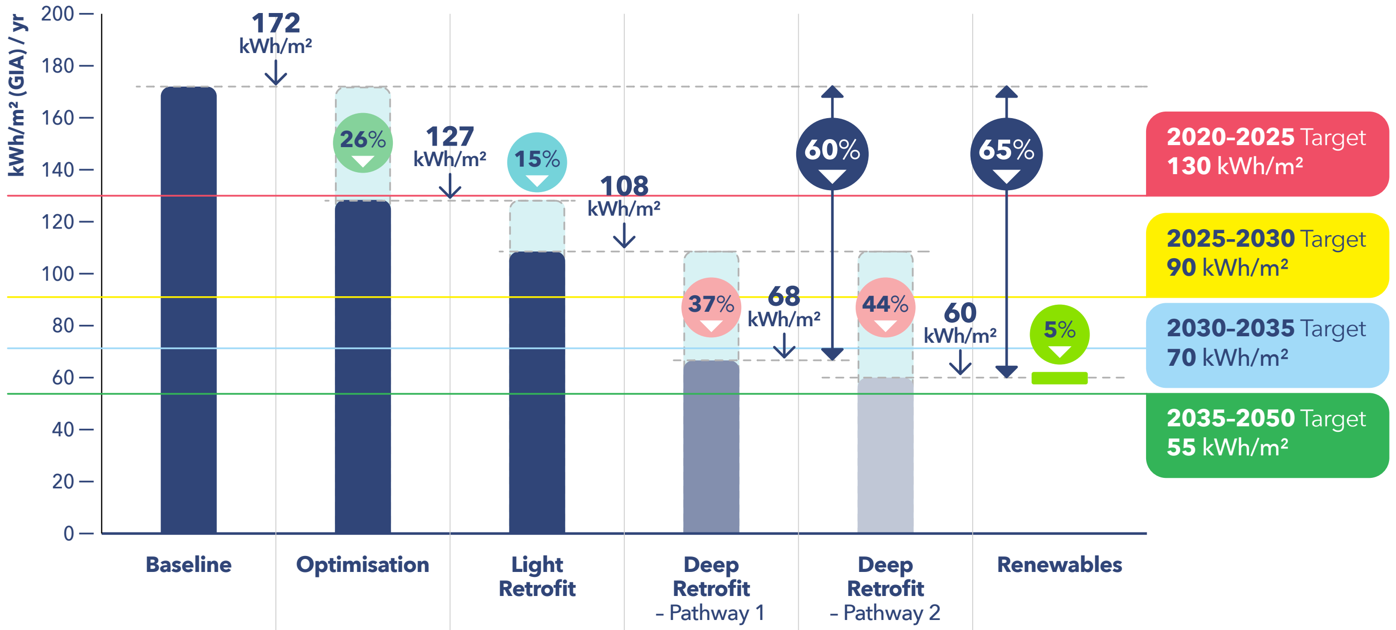


FIGURE 3:
Mean outcomes of EUI reductions of each retrofit phase over median baseline EUI. EUI reductions based on the aggregated mean impacts of each retrofit measure.

SCOPE	RETROFIT MEASURE	WHOLE BUILDING EUI (kWh/m2(GIA)/year)		EUI REDUCTION (%) Mean impact	EUI REDUCTION (%) Cummulative impact
		Range	Mean		
Median baseline of all datasets:			**172**		
OPTIMISATION	• BMS upgrade / health check. • Reduce tenant equipment loads.	106-164	127	**26%**	**26%**
LIGHT RETROFIT	• Pump motor replacement • Lighting controls • Low energy lighting	60-162	108	**15%**	**37%**
DEEP RETROFIT PATHWAY 1	• Roof insulation • Building airtightness • Wall insulation • Window replacement • Decarbonisation of heat (ASHP) • ASHP for DHW	15-146	68	**37%**	**60%**
DEEP RETROFIT PATHWAY 2	• Roof insulation • Building airtightness • Façade replacement • Decarbonisation of heat (ASHP) • MVHR • CO_2 Ventilation control • ASHP for DHW	12-138	60	**44%**	**65%**
RENEWABLES	Solar PV	n/a	n/a	**5%** of EUI supplied by Solar PV	

TABLE 2:
Impact of retrofit phases on Energy Use Intensity (EUI).

7 KEY FINDINGS

7.1 IMPACT OF INDIVIDUAL RETROFIT MEASURES

RANGE OF OUTCOMES

For several retrofit measures, a wide range of possible EUI reductions were observed, as well as a wide range of costs. This is primarily due to the differing office building types evaluated, as well as differing solutions implemented; or extent of solution, e.g., an air source heat pump (ASHP) that only serves landlord areas will have a lesser impact on overall EUI than a system that serves the whole building.

Greater impacts tended to be found through retrofitting less efficient buildings, but this was often at a greater cost per square metre. It was not possible to make comparisons on a like-for-like basis due to the complexity and diversity of retrofit solutions presented through project datasets, however, further detail around how and why costs and impacts vary is provided in the breakdowns in **Appendix 4**.

RELATIONSHIP WITH BUILDING AGE

Project datasets were initially divided into building age categories, denoting the era of original construction and thereby the building standards and conventions typical of that time, to ascertain whether certain measures were more appropriate, or more impactful to a particular age of building, as follows:

T1 Heritage building pre–1964.

T2 Building constructed 1964–1984.

T3 Building constructed 1985–2001.

T4 Building constructed 2002–2012.

The overall range of baseline EUI was between 123 kWh/m² to 523 kWh/m², with the 523 kWh/m² being a distinct outlier in the T3 category. There was no clear correlation between EUI and building age, and there did not appear to be any clear correlation between age category and retrofit outcome. This may be due to the fact most older buildings are likely to have undergone several refurbishments in their history, or that the number of permutations of fabric standards, glazing proportions, building services and operational uses, etc., goes far beyond the categories tested. The number and range of datasets limited further analysis around building type and impact.

INTERDEPENDENCIES

The results are presented as if each retrofit measure is implemented as a standalone intervention, yet there are numerous interdependencies between many of the measures, which could either serve to increase or decrease the combined outcome, for example:

- Efficient luminaires produce less waste heat than traditional lighting systems, increasing heating requirements, yet decreasing cooling loads.
- Improved air tightness is often a co-benefit of window replacement, so the results may be interconnected.
- Should significant fabric improvements be made before, or at the same time as the installation of heat pump systems, heat pumps could be sized for lower energy loads with substantially lower embodied carbon and costs.
- Generally, apart from window replacements, when considered as stand-alone measures fabric interventions were found to have high relative embodied carbon impact. Yet, fabric improvements are often integral to achieving the highest energy performance standards, and, as noted above, making fabric improvements earlier in a retrofit strategy can result in compounded savings through reduced plant sizes. However, caution needs to be practised to ensure that:

- [x] Fabric upgrades are scheduled to be carried out at, or near the end of life of components replaced.
- [x] Whole life carbon assessments support an evidence-based approach to material and product specification.
- [x] Lower embodied carbon materials and products are specified to drive down upfront embodied carbon.

7.2 PATHWAYS TOWARDS NET ZERO

OPTIMISATION AND LIGHT RETROFIT

The pathways illustrate that significant reductions in EUI can be achieved through both optimisation (27%) and light retrofit (15%), with optimisation having the highest immediate potential for EUI reduction. Both these phases can be landlord or tenant led, and success depends on effective collaboration between all stakeholders, leveraging the skills of facilities managers to ensure all parties 'see' how building performance responds to interventions.

- **Optimisation** includes the most cost-effective measures with the lowest relative embodied carbon impact, yet there may be little associated impact on EPC rating. It is also the most 'noticeable' phase, requiring practical adjustments to how we use offices and behavioural change, (e.g., a change in temperature set points for heating and cooling can significantly reduce energy consumption, yet may require an increased tolerance and/or flexibility during both hot and cold spells, and shifts in social norms).
- **Light Retrofit** measures may also require close collaboration between tenant and landlord when carried out while spaces are occupied, due to the potential disruption associated with some measures. However, the EUI reduction is less dependent on any noticeable adjustments to operations or behaviour change. An 'average' light retrofit is unlikely to enable office buildings to reach the 2025-2030 EUI targets of 90 kWh/m^2, though it may be possible should above average EUI reductions be achievable.

DEEP RETROFIT

An 'average' office building is likely to require deep retrofit to reach the 2030-2035 EUI targets of 70 kWh/m^2, and enable the transition away from fossil fuel heating systems. 2035-2050 EUI targets of 55 kWh/m^2 were not achieved using average EUI reductions yet could be achievable should each retrofit measure's impact be greater than average, and positive interdependencies are fully leveraged. The average level of EUI reduction achieved is significant, however, and is also likely to result in significant whole life carbon savings when compared to demolition and new build, as illustrated by several of our later case studies.

MEETING FUTURE NET ZERO TARGETS

Yet, this also demonstrates that most current retrofit projects are not driving down operational energy use sufficiently to meet medium-term 2035–2050 decarbonisation trajectories, and ambitions need to be raised for future projects. When deep retrofits are carried out on listed buildings or within conservation areas, the depth and scale of retrofit can be limited by planning and/or heritage concerns. For future decarbonisation trajectories to be met an appropriate balance is required, so that our planning system encourages retrofit, and supports our net zero commitments.

Integral to maximising EUI reductions at both light and deep retrofit, is the assumption that building performance has been optimised, and operational energy use reduced from both a landlord and a tenant perspective. Optimisation depends on continued monitoring and sharing of data to prevent 'slip back', where performance gradually reverts to previous consumption levels as behaviours revert to previous norms. Performance-based policy frameworks and/or performance-based certification systems like NABERS UK, could support greater awareness and understanding of the need to monitor energy use in operation.

To reduce energy consumption and maintain performance levels for the long term, we need close collaboration and a common vision between all stakeholders, so that behaviour change is embedded, and all parties are invested in a net zero focused outcome.

7.3 COST EFFECTIVENESS OF INDIVIDUAL RETROFIT MEASURES

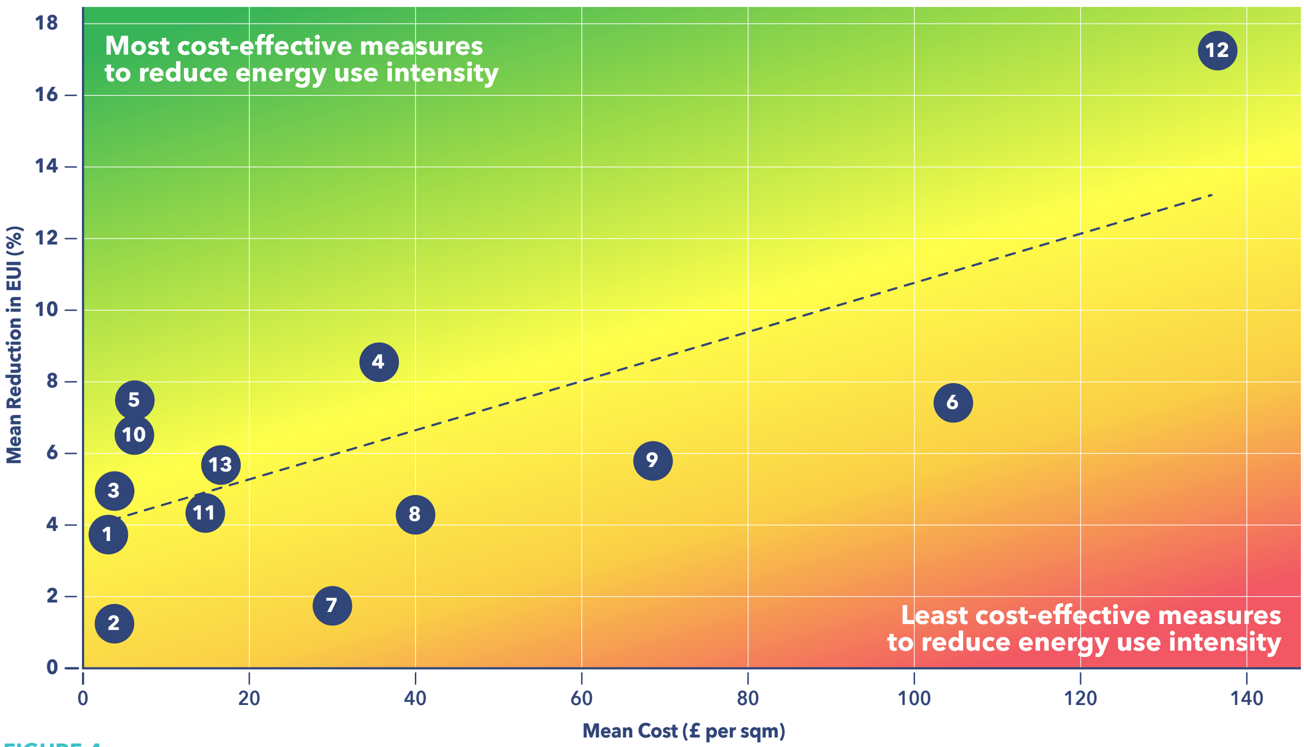


FIGURE 4:
Mean reduction in EUI of retrofit measures against the cost per square metre.

The above analysis of individual measures illustrates their respective level of energy reduction impact, compared to their cost. As noted previously, there are a wide range of both impacts and costs, so both the mean and range of values are shown where possible.

Overall, there appears to be a modest relationship between carbon impact and cost, seen through the measures concentrated around the central yellow area. Measures that are shown towards the green end of the spectrum tend to be more cost effective, having more relative impact per £ spent, while those towards the red are more costly for the impacts achieved. Nevertheless, as noted previously, most retrofit projects will require all measures to be implemented to close the gap towards net zero.

1. BMS health check
2. Pump motor replacement
3. Lighting controls
4. Low energy lighting
5. Building airtightness
6. Window replacement
7. Roof insulation
8. Wall insulation
9. MVHR
10. CO_2 ventilation control
11. ASHP for DHW
12. Decarbonisation of heat (ASHP)
13. Solar PV

8 SUMMARY

8.1 CONCLUSIONS

- Building optimisation can have a significant impact on energy use, but the lack of accessibility to, and transparency of data is a key barrier. Office buildings are complex dynamic systems that include physical, technological, and human components. Lack of transparent data is preventing key feedback loops, (e.g., occupants or facilities managers who can see the energy impact of their actions are more motivated to change behaviour accordingly).
- Long term optimisation will change the way we use our offices, as building performance is balanced with employees' health and wellbeing, shifts in flexible working, and alternative approaches to how, when, and where we work. Collaboration across all stakeholders is key to ensure all parties are invested in a net zero focused outcome, and that any unintended consequences of workplace shifts are fully considered.
- Early identification of 'trigger points' that determine when both light and deep retrofits could occur, should set out the most effective pathways towards net zero, in terms of disruption, cost, and whole life carbon. Due to the complexity of drivers and constraints, there is no one ideal pathway towards net zero, and long term retrofit strategies will need to evolve as both opportunities and pressures shift, and circumstances change.
- Intermediate steps can be carried out through light retrofit in advance of deep retrofit, not only to reduce energy consumption in the short term, but also so that deep retrofits can be carried out more swiftly, with less extensive works when opportunities do arise.
- To transition away from fossil fuels, we need to prioritise strategies that decarbonise heat (e.g., replacing gas boiler-fed heating systems with heat pumps), which often requires deep retrofit. This strategy also has the most impact on improving EPC ratings.
- Switching to heat pump systems without first improving the building fabric, could result in oversized plant with the associated additional costs and carbon, unless a phased, or hybrid strategy is considered.
- Interventions that improve fabric efficiency are necessary to facilitate the reductions in operational energy performance we need to meet top-down sectoral net zero targets. However, given the potentially high whole life carbon impact of fabric interventions, they are most effective when part of wider maintenance and repositioning strategies, and to facilitate the installation of more efficiently sized heat pump systems.
- Average retrofit projects being carried out at this time are not reaching the reductions in operational energy performance we need to meet top-down sectoral net zero targets. Efforts need to be redoubled and ambitions raised, to ensure the decarbonisation potential of future retrofit opportunities are realised.

8.2 KEY CONSIDERATIONS FOR RETROFIT STRATEGIES

In contrast to new build where a 'fabric first' approach is generally the most effective way to deliver energy efficiency, there is no one ideal pathway towards net zero for existing office buildings. For office retrofit, the order in which measures should be implemented depends primarily on the timings of trigger points:

1. **Opportunities** in lease cycles that enable light or deep retrofits to be carried out.
2. **Opportunities** in maintenance and refurbishment cycles – especially when building components are nearing their end of life – that mean upgrades have marginal cost and marginal whole life carbon impact.

This necessitates a long-term strategic approach to retrofit, that encourages and priorities action now, while planning for the future.

We found that the impact of similar measures varied significantly across the projects analysed, highlighting the importance of carrying out building-specific assessments to determine building-specific outcomes, and the importance of maximising impacts achieved wherever possible. With clearer understanding of what could be achieved through each retrofit measure and retrofit phase, net zero focused retrofit projects should set ambitions higher to accelerate progress.

9 CASE STUDIES

The following sections include a 'worked example' and real-world project case studies, both aimed at exploring retrofit strategies in practice. The worked example consists of an anonymised project drawn from the Task Group, which has been used to test the methodology set out through this project and demonstrate how it can inform the decision-making process. The real-world case studies bring to life examples of how and when to implement different retrofit strategies, exploring both current drivers and barriers to further progress, and also demonstrating how a focus on the wider benefits of retrofit strengthens long-term value.

9.1 WORKED EXAMPLE

BASELINE BUILDING OVERVIEW

The baseline building is a live project drawn from the task group, where we were able to model the impact of individual retrofit measures as well as different phases of retrofit so as to explore impacts in more detail.

The proposed project includes both the retrofit and redevelopment of an existing 6-storey office building in Central London originally constructed in 1983. Baseline and proposed specifications are detailed below:

- **Baseline EUI =** 160.6 kWh/m²/yr
- **Baseline EUI =** C (rating 65)
- **Window area =** 39%, wall area = 61%

PROPOSED RETROFIT AND REDEVELOPMENT

The proposed retrofit includes fabric upgrade measures including partial facade replacement, improved M&E services, and the installation of solar PV, as detailed in Table 3. The redevelopment included partial demolition works which retained the existing structural frame, a 3-storey rooftop extension that incorporates additional office floorspace, and new external roof terraces to improve amenity.

BASELINE BUILDING	RETROFIT IMPROVEMENT
Fabric	
Air-tightness = 25 m³/hr.m² at 50Pa	Air-tightness = 3.0 m³/hr.m² at 50Pa
Wall U-Value = 1.0 W/m²K	Wall U-Value = 0.18 W/m²K
Roof U-Value = 0.6 W/m²K	Roof U-Value = 0.11 W/m²K
Glazing U-Value = 5.7 W/m²K	Glazing U-Value = 1.4 W/m²K
M&E	
Lighting = 20 W/m²	Lighting = 4.5 W/m²
Heating & DHW via 85% efficient gas boiler	Heating, DHW & Cooling via ASHP
Ventilation via AHU with no heat recovery at a SFP of 2.5 W/l/s	Ventilation via AHU with 85% heat recovery at a SFP of 1.6 W/l/s
Cooling via old chiller 2.0 EER & 2.5 SEER	Shading
	Night Purge to run overnight if the external temperature is above 10°C
	PV's with an active area of 200m² and an annual yield of 160 kWh/m²
Other	
Lighting = 20 W/m²	Lighting = 4.5 W/m²
Cooling via old chiller 2.0 EER & 2.5 SEER	Shading

TABLE 3: Specifications of original baseline building and retrofitted building.

IMPACT OF INDIVIDUAL RETROFIT MEASURES

To demonstrate and test the retrofit strategy outlined in this report, we applied the methodology to the IES model of the baseline building. A range of common retrofit measures were applied to the baseline model and their impacts were assessed individually, as illustrated in Table 4 and described in the narrative below.

	Measure Type	Impact on Baseline Energy Use Intensity (EUI) 'Reduction' (Increase 10% / Decrease 10% 20% 30%)	Percentage Impact of Retrofit Phase on EUI	Combined Impact on Whole Building EUI (kWh/m² (GIA)/year)	Cost of Retrofit Phase (£)	Cost per m2 GIA (£/m²)
				Pre-retrofit = 160.6		
Optimisation	BMS Replacement	-3.8%	-18.6%	130.7	£751,240	£40
	Reduced Tenant Loads	-15.4%				
Light Retrofit	Low Energy Lighting	-16.7%	-6.9%	121.6	£2,661,195	£142
	Shading	-0.1%				
	Mixed Mode Ventilation	-3.3%				
	Night Purging	-2.6%				
Deep Retrofit	Airtightness	+4.6%	-36.8%	76.9	£20,871,585	£1,111
	Wall Insulation	-0.8%				
	Roof Insulation	-0.3%				
	Glazing Upgrades	-4.4%				
	ASHP for Heating, DHW & Cooling	-22.7%				
	MVHR	-32.6%				
Renewables	Solar PV	-1.1%	-1.1%	76.9	£100,000	£5

TABLE 4: The Impact of individual retrofit measures, as implemented in the worked example.

Improved Building Fabric

Air Tightness

Improved air tightness actually increases EUI when introduced as a standalone measure. This is because reduced air leakage results in increased overheating, and so leads to greater cooling loads and the associated use of pumps/fans.

Wall Insulation

The EUI decreases due to the improvement of the external wall's thermal properties. This means more heat is retained so the heating load decreases. However, the impact is limited due to high glazing ratios, and a slight increase in cooling load.

Roof Insulation

The EUI decreases due to the improvement of the roof's thermal properties. This means that more heat is retained so the heating load decreases. However, the impact is limited due to a smaller roof area as compared to the façade (roof insulation will only impact top-floor areas). There is also a slight increase in cooling load.

Glazing Improvements

The EUI decreases due to the improved thermal properties of glazed façades. Heat is more effectively retained, or kept out, decreasing demand on both the heating and cooling loads. This has a relatively large impact on the EUI due to large area of glazed façade.

Improved M&E

Low Energy Lighting

The EUI decreases due to the large reduction in lighting loads which subsequently also decreases the cooling load.

Shading

The EUI decreases only by a small amount. This is because the decrease in cooling load is offset by an increase in heating load. While the building is leaky without air tightness improvements, the reduction in solar gain to reduce cooling load isn't as beneficial.

ASHP

The EUI decreases by a relatively large amount as the ASHP is far more efficient than original gas boiler.

Mixed-mode Ventilation

The EUI decreases by a small amount as there is a large decrease in cooling loads due to free cooling via natural means. There is also a small decrease in the fan and pump energy as a result.

Night Purge

The EUI increases by a small amount. Cooling loads decrease, especially around the summer months. However, due to the building having poor airtightness, benefits are limited.

MVHR

The EUI decreases significantly as implementation of MVHR causes a significant reduction in Specific Fan Power (SFP) alongside heat recovery, meaning less heat is wasted. This intervention is more extensive than those provided within the anonymised datasets, so have greater impact and higher costs.

Renewables

Solar PV

The net EUI decreases from baseline by a small amount, as expected, due to the PV offsetting only a small amount of the building's energy usage. A more energy-efficient building could benefit more, as it would consume less energy. This is also dependant on roof area availability.

COSTS OF INDIVIDUAL RETROFIT MEASURES

Costs provided are current day (4Q23), and assume all works are carried out during normal working hours and in sequence, as part of a wider refurbishment project on a vacant building. Costs generally depend on the level of specification of the building, and mid-range is assumed. For detailed assumptions and exclusions, please refer to **Appendix 4**.

TABLE 5:
Costs of individual retrofit measures and associated assumptions.

MEASURE	SOLUTION	COST	COST (£/M²)	NOTES
Air-tightness	Full glazing replacement.	-	–	Included within full glazing replacement.
Wall Insulation	Full façade replacement.	**£9,870,197**	£526	Rate includes for removal of existing façade system.
Roof Insulation	New roof.	**£1,669,422**	£89	Rate includes for removal of existing roof finishes and replacement with new. Assumed flat inverted roof.
Glazing	Full glazing replacement including frame.	**£4,278,000**	£228	Double glazed windows. Assumes a proportion are openable.
Low Energy Lighting	Upgrade to LED lighting.	**£1,784,195**	395	Includes new lighting and associated controls to landlord and tenant areas.
Shading	–	-	–	Included in façade build up.
ASHP	Upgrade to ASHP including full pipework replacement.	**£2,021,587**	£108	Assumed total loading of 3,750kW.
Mix Mode Ventilation	BMS operated automatic windows using sensors.	**£877,000**	£47	Includes BMS connection, actuator and thermal sensor. Assumes approximately 50% of openable windows have automatic.
Night Purge	–	-	–	Included within other mechanical elements.
MVHR AHU	New heat recovery AHU including ductwork replacement	**£3,032,380**	£161	New ventilation system including new heat recovery AHU and ductwork, CAT A office fit out excluded
Solar PV	–	**£100,000**	£5	Panels + frame and cabling back to an inverter. Excludes battery storage. 160kWh/m².
BMS	BMS upgrade.	**£751,240**	£40	New BMS system including tenant panels. CAT A office fit out excluded.
Reduction of Tenant Equipment	Utilise offsite servers (tenant modifications).	-	–	Not applicable as part of tenant's occupational requirements.

RETROFIT

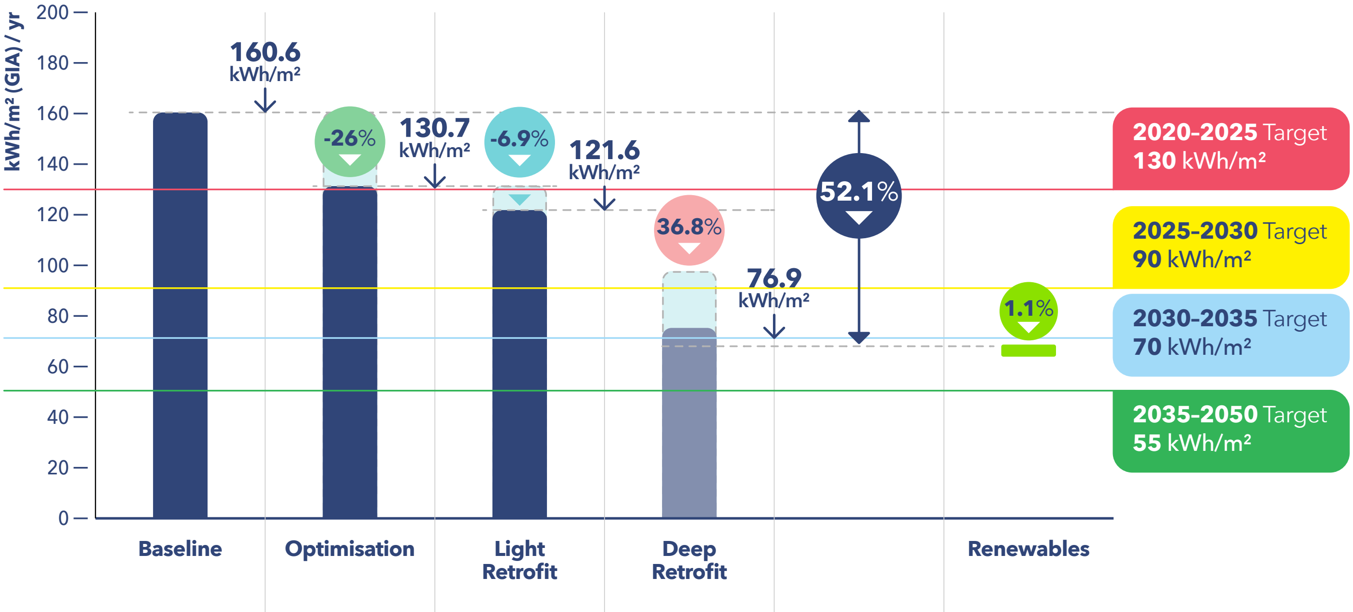


FIGURE 5:
The impact of each retrofit phase.

RETROFIT PHASES

SCOPE	ROOF MEASURE	WHOLE BUILDING EUI kWh/m2(GIA)/year	EUI REDUCTION from baseline (%)	COSTS (£)	COSTS PER M² GIA (£/m²)
Baseline EUI		160.6			
Optimisation	BMS replacement. Reduce tenant equipment loads	130.7	**-18.6%**	£751,240	£40
Light Retrofit	Low Energy Lighting, Shading, Introduction of Mix Mode Ventilation, Night Purge to run overnight if the external temperature is above 10 degrees celsius.	121.6	**-24.2%**	£2,661,195	£142
Deep Retrofit:	Airtightness, Wall insulation, Roof insulation, Glazing upgrades, ASHP for Heating, DHW & Cooling, MVHR.	76.9	**-52.1%**	£20,871,586	£1,111
Renewables	Solar PV		**-1.1%**	£100,000	£5

TABLE 6:
Impact and costs of retrofit phases.

Optimisation

The BMS upgrade reduces the baseline EUI by a small amount as it would save energy across the entire building by shifting the user demand. This, in addition to reducing the tenant load could provide the same saving as Low Energy Lighting to the entire building.

Light Retrofit

The EUI decreases from baseline by around 7% in isolation. However, when the savings from the optimisation stage are included, this equates to an approximate EUI reduction of 24%. Large savings are found in cooling and lighting loads when improved systems are aligned with improved controls.

Deep Retrofit

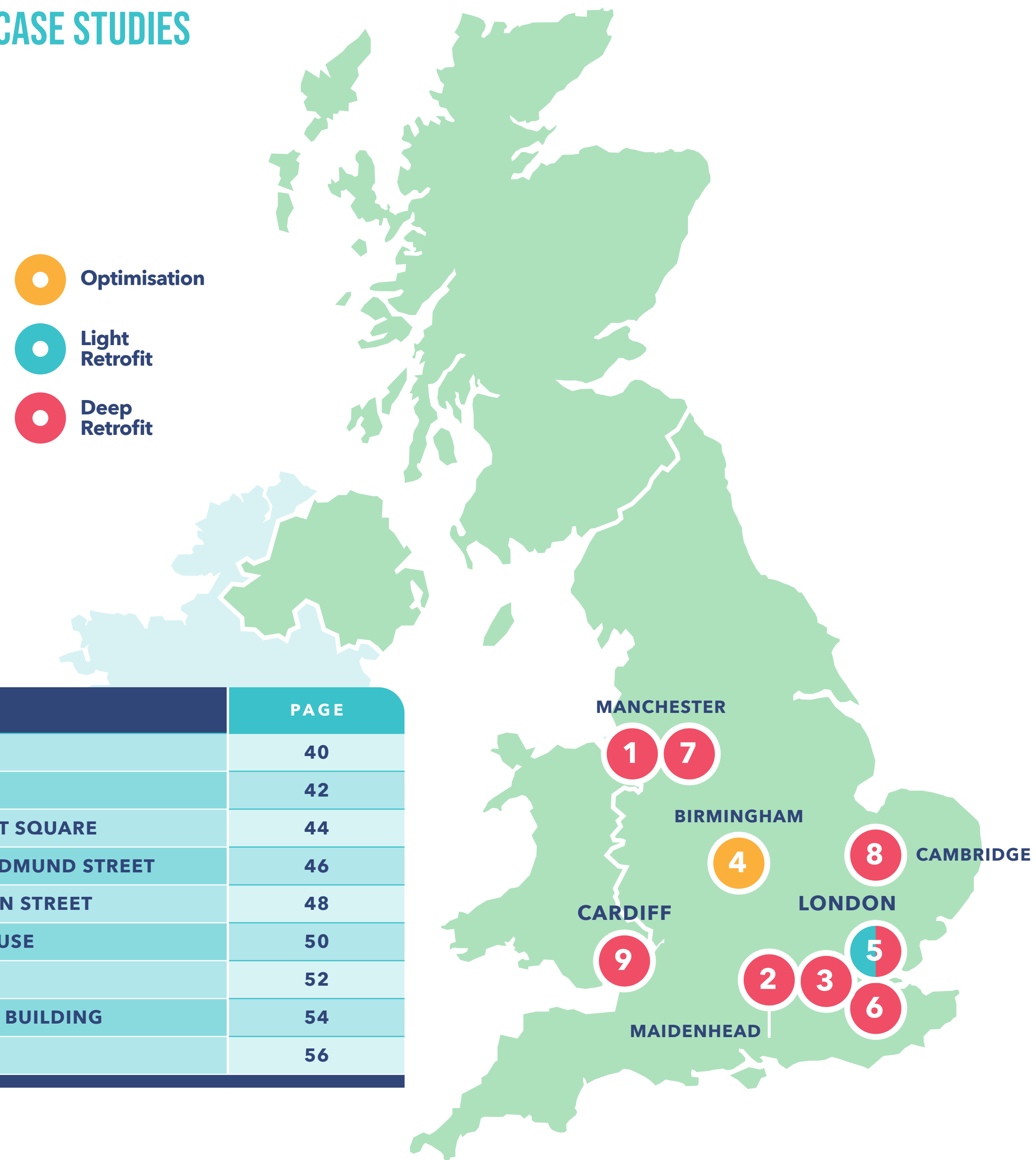
The EUI decreases from the baseline by a significant amount during the deep retrofit stage. Large savings found due to the installation of ASHP's and MVHR's in addition to the reductions achieved in the light retrofit.

SUMMARY

When comparing the impact of individual measures with a phased pathway, it is clear that a strategic approach is needed to ensure that the thermal properties of the building envelope are considered holistically and align with building systems' operation. Air tightness, for example, actually increases EUI when implemented as a standalone measure due to the knock-on impacts on cooling loads, yet when implemented in combination with measures to address overheating, is an effective way to reduce EUI.

Although deep retrofit is essential for deep cuts in emissions, both optimisation and light retrofit offer significant opportunities for energy and costs savings in the short- to medium-term

9.2 PROJECT CASE STUDIES



CONTENTS		PAGE

There are 9 named case studies referenced within this section of the report. These are also available in full in the UKGBC Solutions Library and will be updated as the projects progress.

	NAME	OFFICE TYPOLOGY	TYPE OF RETROFIT	LOCATION	DESIGN STATUS	ACTUAL OR EXPECTED COMPLETION DATE
1	**Pall Mall**	T2	Deep	Manchester	Construction	2025
2	**Tempo**	T3	Deep	Maidenhead	Construction	2024
3	**5 New Street Square**	T4	Deep	London	Design	2025
4	**134-138 St Edmund Street**	T1	Tracking and Optimisation	Birmingham	In-use	Ongoing
5	**1&2 Stephen Street**	T2	Light and Deep	London	Phase 1 – In-use Phase 2 – Construction	Phase 1 – 2014 Phase 2 – 2024
6	**Minerva House**	T2	Deep	London	Design	2026
7	**Havelock**	T4	Deep	Manchester	Construction	2024
8	**The Entopia Building**	T1	Deep	Cambridge	In-use	2022
9	**Coal House**	T3	Deep	Cardiff	In-use	2024

TABLE 7:
Overview of project case studies.

- **T1** – Heritage building constructed pre-1964.
- **T2** – Constructed 1964–1984.
- **T3** – Constructed 1985–2001.
- **T4** – Constructed 2002–2011.

**The type of retrofit is based on the categories from the overarching strategy in the main report.
Tracking and optimisation, light retrofit, deep retrofit.

Pall Mall

Manchester

Pall Mall is located on King Street and sits in the heart of Manchester City Centre. Originally constructed in 1969, this Grade II listed building had sat vacant for almost four years before being acquired by Bruntwood in 2021.

Due to the poor energy inefficiency of the building, in part due to the existing glazed façade, it was at significant risk of becoming a stranded asset. This presented a clear opportunity to upgrade the building to modern sustainability standards, not only to reduce the energy consumption, but also to attract tenants with strong sustainability credentials and increase the rental value.

A Whole Life Carbon Assessment was carried out to establish the carbon impact of maintaining and retrofitting the building compared to alternative scenarios such as new build. The analysis concluded that carrying out a deep retrofit would be the most carbon efficient solution (as shown in Figure 5). This was, in part, due to the proposed switch away from gas heating to hybrid variable refrigerant flow (HVRF), with an air source heat pump (ASHP) serving domestic hot water and air handling unit (AHU) coils (as shown in Figure 6).

This deep retrofit case study highlights the significant reduction in energy use intensity – 74% in this scenario – that can be achieved through retrofitting within a Grade II listed building and demonstrates why it is important to evaluate emissions from a whole life carbon perspective when considering whether to carry out a retrofit or a new build.

PROJECT OVERVIEW

Office Typology: **T2** – Constructed 1964-84
Location: Manchester City Centre
Type of Retrofit: Deep
Partners: Client: Bruntwood
Architect: Sheppard Robson
MEP & Sustainability Consultant: Ramboll
Planning Consultant: Deloitte
Main Contractor: Dragonfly
Design Status: Construction
Expected Completion: Early 2025
Project Size: 85,000sqft NIA

PROJECT ACHIEVEMENTS

- 74% reduction in EUI
- EPC improvement from G to A
- Rental value uplift from £12-15 to £35-37 per sq. ft.
- BREEAM Very Good

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

- **Resource Use**
- **Climate Change Adaption**
- **Health, Well-being and Social Value**

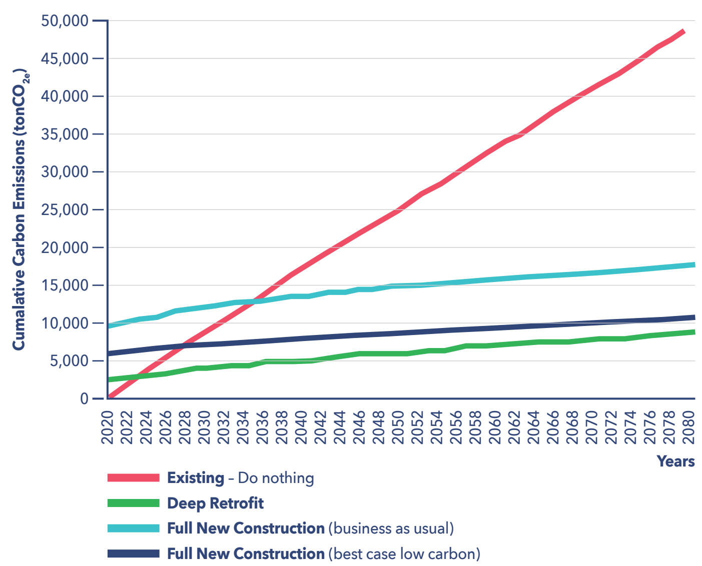


FIGURE 5:
Whole Life Carbon Timeline (in tons).

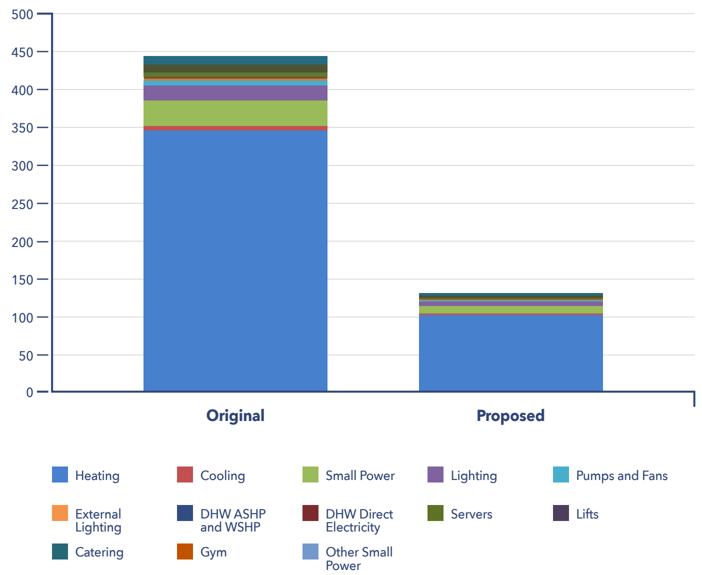


FIGURE 6:
Annual Energy Consumption of original and proposed building (kW/m²).

Tempo
Maidenhead

Previously the office of a telephone operator, Tempo is being retrofitted into multi-let offices for up to 11 tenants in Maidenhead city centre.

The client became a signatory to the Better Buildings Partnership Climate Change Commitment and therefore pledged to achieve net zero carbon for their real estate portfolio. As the current building lease was due to expire, it presented an opportunity to improve the efficiency of the building in line with these targets, whilst also increasing the rental value and attracting tenants that have their own ambitious sustainability targets.

Most of the structure and façade are being maintained to reduce the embodied carbon impact (as shown in Figure 7). The existing services, which were supplied by gas boilers at a local onsite energy centre, are coming to the end of their lifecycle and will be replaced with Air Source Heat Pumps (ASHP) for heating, cooling and hot water. Other retrofit interventions include improving the efficiency of the Air Handling Units, implementing demand-led ventilation and refining the fabric performance.

The project followed the NABERS Design for Performance (DfP) framework and achieved a design stage 5* rating, with a commitment from the client to achieve this in use. To do this, plant efficiencies needed to be maximised and pressure drops in ductwork had to be reduced, which required more space than typical installations.

Any spaces that operated out of hours, such as cafes, had to be on independent systems to avoid using the main central plant for small loads. Minimising refrigerant leakage and using a low Global Warming Potential (GWP) refrigerant was also a priority and was a key factor in why an ASHP solution was progressed as opposed to a Variable Refrigerant Flow system (VRF).

PROJECT OVERVIEW

Office Typology: **T3** – Constructed 1985-2001
Location: Maidenhead, Bucks
Type of Retrofit: Deep
Partners: Client: Legal & General
Architect: Sutton CA
MEP/Sustainability/Fire/Acoustics/VT: Hoare Lea
Structural Engineer: Clancy
Visualisation: Arko
Design Status: Construction
Expected Completion: January 2024
Project Size: 21,464 sqm GFA

PROJECT ACHIEVEMENTS

- EUI reduction 23% below UKGBC 2020-2025 target
- EPC improvement from D to B
- Rental uplift 20% above local market rates
- BREEAM Excellent
- NABERS 5*
- WiredScore Platinum

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

Health, Well-being and Social Value

Embodied Carbon of Tempo compared to the RIBA targets

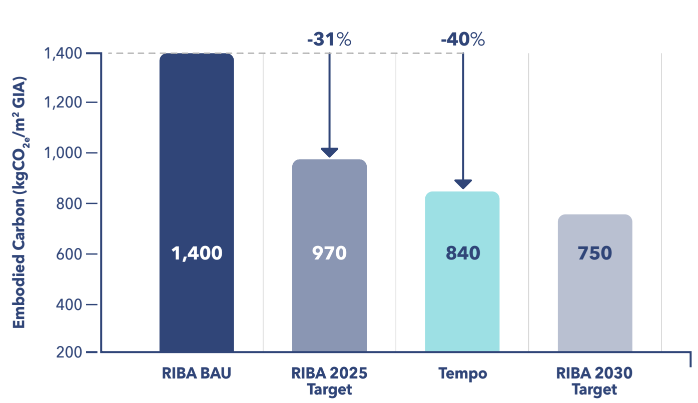


FIGURE 7:
Embodied carbon of Tempo Baseline compared to the RIBA 2025 target (RIBA Lifecycle stages A1-A5, B1-B5, and C1-C4).

Operational Energy Performance of Tempo against industry benchmarks

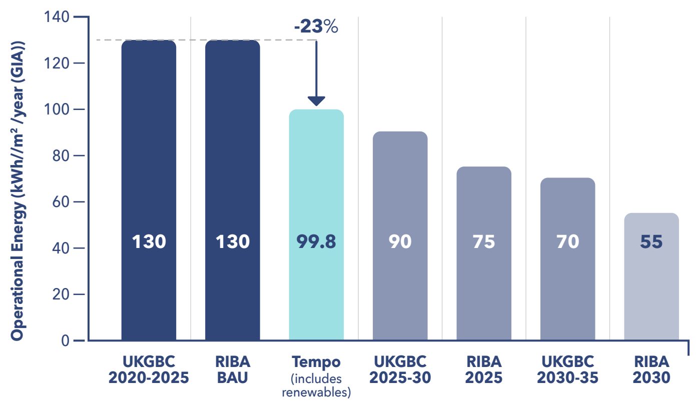
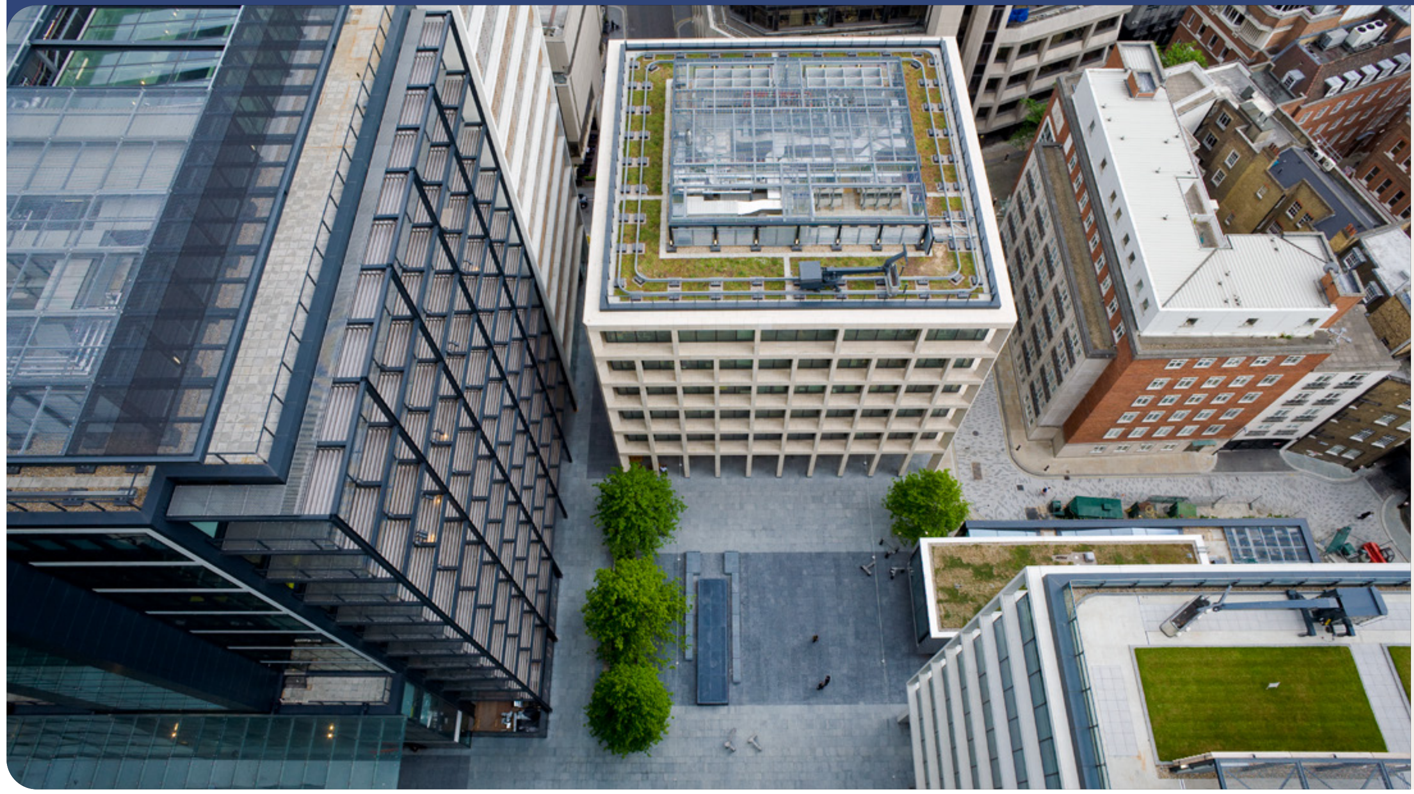


FIGURE 8:
Comparison of Tempo operational energy performance against industry benchmarks for operational energy.

5 New Street Square
London



New Street Square (NSS) was constructed in 2008 in the City of London, creating a new destination between High Holborn and Fleet Street, with five buildings set around a new public square.

With the main lease coming to an end, a key motivator for retrofit was retaining the existing tenant, for which net zero operation and well-being had become increasingly significant factors. A major lease event provided a clear opportunity for a deep retrofit.

In order to establish the most effective retrofit measures for meeting the energy use targets, a net zero carbon roadmap was developed and modelled. Despite achieving a potential improvement in overall u-values from 1.9 to 1.4, it was quickly established that a replacement façade was costly and disruptive and that the improvement in energy performance was insufficient to offset the upfront carbon impact. The focus of the strategy has therefore been on a centralised plant and floorplates, combined with a move to an all-electric operation. Fabric improvements may be considered at the next lease event.

The four most significant energy savings that had relatively little impact on the use of the building were – in descending order – ASHPs, HVAC upgrades, lighting improvements, and mixed-mode operation. More noticeable changes, such as tenant IT (mostly cloud servers) and behaviour (temperature set points, dress codes, and remote-working approach), were upgrades which the landlord had limited operational control over.

PROJECT OVERVIEW

Office Typology: **T4** – Constructed 2002-2011

Location: New Street Square, London

Type of Retrofit: Deep

Partners: **Client:** Landsec
Architect: Bennetts Associates
MEP Engineer: Cundall
Planning Consultant: Deloitte,
Main Contractor: Dragonfly

Design Status: Design stage, Q4 2024

Expected Completion: Q1 2025

Project Size: 28,734 GIA (exc. basement)

PROJECT ACHIEVEMENTS

- EUI from 295Wh/m²/yr to 135kWh/m²/yr
- EPC B rating minimum
- NABERS 5 star
- Well Gold enabled
- Upfront carbon no greater than 225kgCO2e/m² A1-5 (LETI band A+)

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

Resource Use

Health, Well-being and Social Value

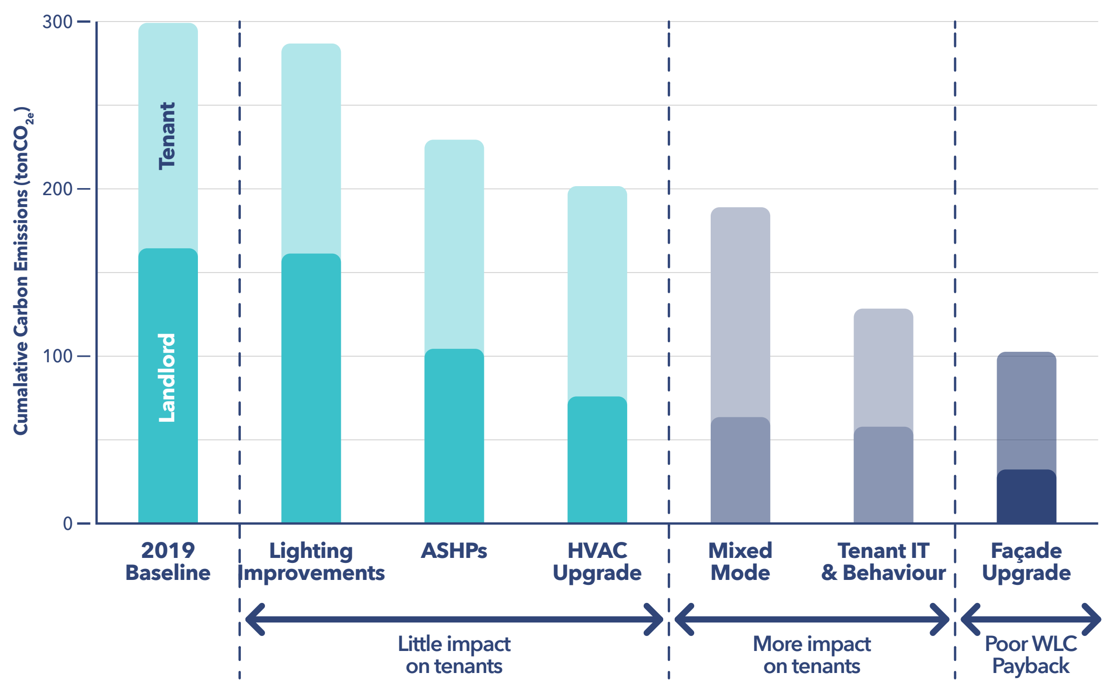
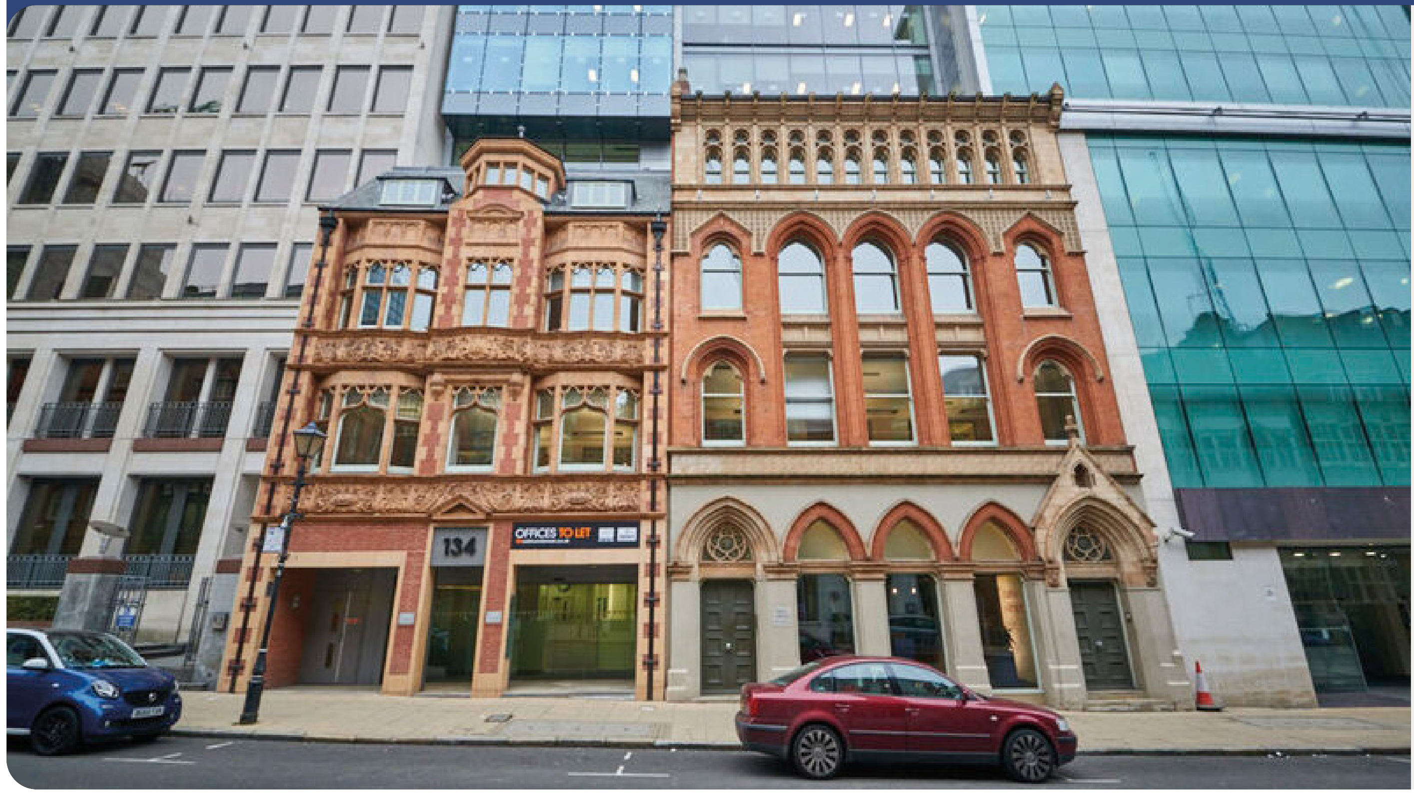


FIGURE 9:
Building intervention timeline.

134-138 St Edmund Street

Birmingham



The property is located fronting both Edmund Street and Cornwall Street in the heart of Birmingham's central business centre.

Driven by the commitment to achieve net zero and ESG targets and to improve occupant well-being, the client focused on optimising the existing building performance. To do this, the Demand Logic software was embedded to gather information from over 4,300 data points including internal environmental temperatures, details of conditioning units, boilers, refrigeration systems and ventilation systems. The live data was then modelled and anomalies in operation highlighted for the site team to address.

The software identified inefficiencies such as the plant running times being inconsistent with occupant hours, meaning vacant floors often had air conditioning units running. Flawed air recirculation strategies were also in place that did not fully utilise the available heat recovery/energy conserving functionality, due to ineffective Building Management System (BMS) control.

After the completion of the initial actions to address these issues, the electricity consumption in November/December reduced from a baseline of approximately 4800 kWh/day to 3800kWh/day (-20%), equating to cost savings of more than £100,000. Virtual meters also estimate a reduction of around 25% in gas consumption from boilers. The platform was key in facilitating collaboration between tenants, the landlord and the operations/facilities management (FM) team.

PROJECT OVERVIEW

Office Typology: **T1** – Heritage building constructed pre-1964

Location: Birmingham

Type of Retrofit: Building optimisation

Partners: Client: Grosvenor
Software Developer: Demand Logic

Design Status: In-use

Expected Completion: Ongoing

Project Size: 9,3000m² GIA

PROJECT ACHIEVEMENTS

- EUI reduction of circa 20%*
- Gas consumption reduction of about 25%*

*Based on provisional assessment of initial data.

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

Health, Well-being and Social Value

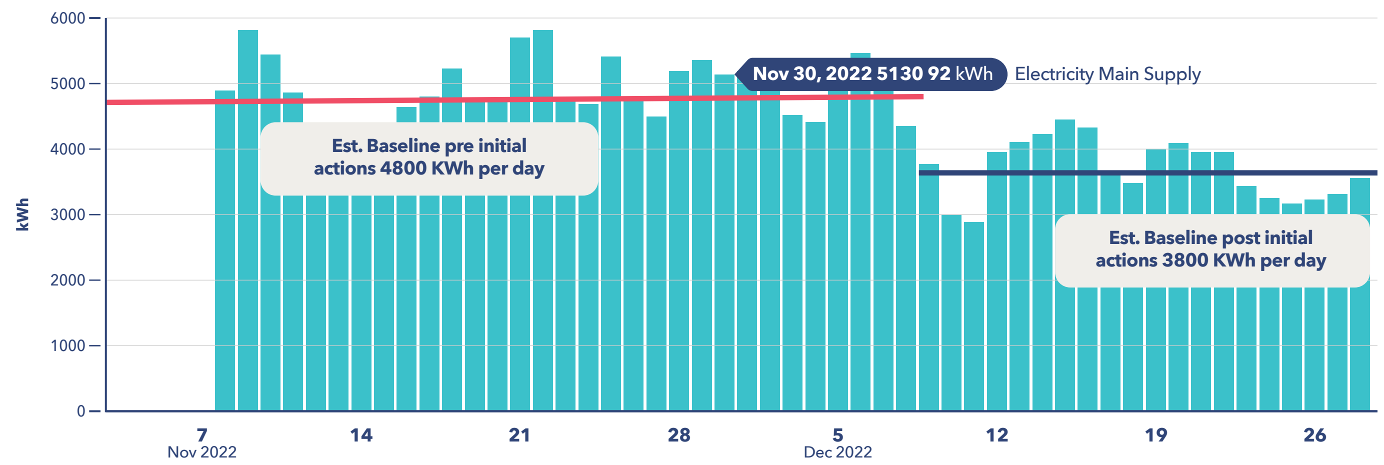


FIGURE 10:
Daily energy pre and post initial actions.

1 & 2 Stephen Street
London

1 & 2 Stephen Street is a mixed-use scheme built in the late 1970s. The building was originally designed with TV studios at ground level in double-height spaces, however, it now consists of retail spaces and a cinema between the basement and ground floor, with ten storeys of offices above.

The retrofit strategy aimed to work around the existing tenants with minimal disruption. This required careful phasing to exploit periods when areas of the building become vacant. A light retrofit of the office spaces was carried out initially to replace the Cat A fit-out with a more efficient solution and to switch from the existing VAV system to minimum fresh air and fan coil units. This was combined with some structural interventions in areas of the building where there is a change of use. Once the office spaces have been retrofitted, a deep retrofit of the central plant will be carried out to replace gas-fired boilers and air-cooled chillers with air source heat pumps.

This phased approach to retrofitting will enable the removal of gas from the building which will make a significant reduction in the operational carbon footprint. Additionally, being able to retain and re-use the existing structure has, and will, save considerable embodied carbon.

From a commercial perspective, the client is able to minimise disruption for the multiple tenants in the building whilst simultanously improving the quality of the space and generate a significant uplift in rental income.

PROJECT OVERVIEW

Office Typology: **T2** – Constructed 1964-84

Location: London

Type of Retrofit: Light & Deep

Partners: **Client:** Derwent London
Architect: Orms
Structural Engineer: Arup
Project Manager: Ramboll
Planning Consultant: Jackson Coles
Main Contractor: Balfour Beatty/ Contrakt/WS Swift

Design Status: Construction

Expected Completion: The first retrofit phase was completed in 2014 and the final phase of retrofit is anticipated to be completed in 2024.

Project Size: 24,700m² (approximate net area)

PROJECT ACHIEVEMENTS

- EUI reduction from 360 kWh/m²/yr – 140 kWh/m²/yr
- From EPC E to A by 2033

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

- Resource Use
- Health, Well-being and Social Value
- Nature

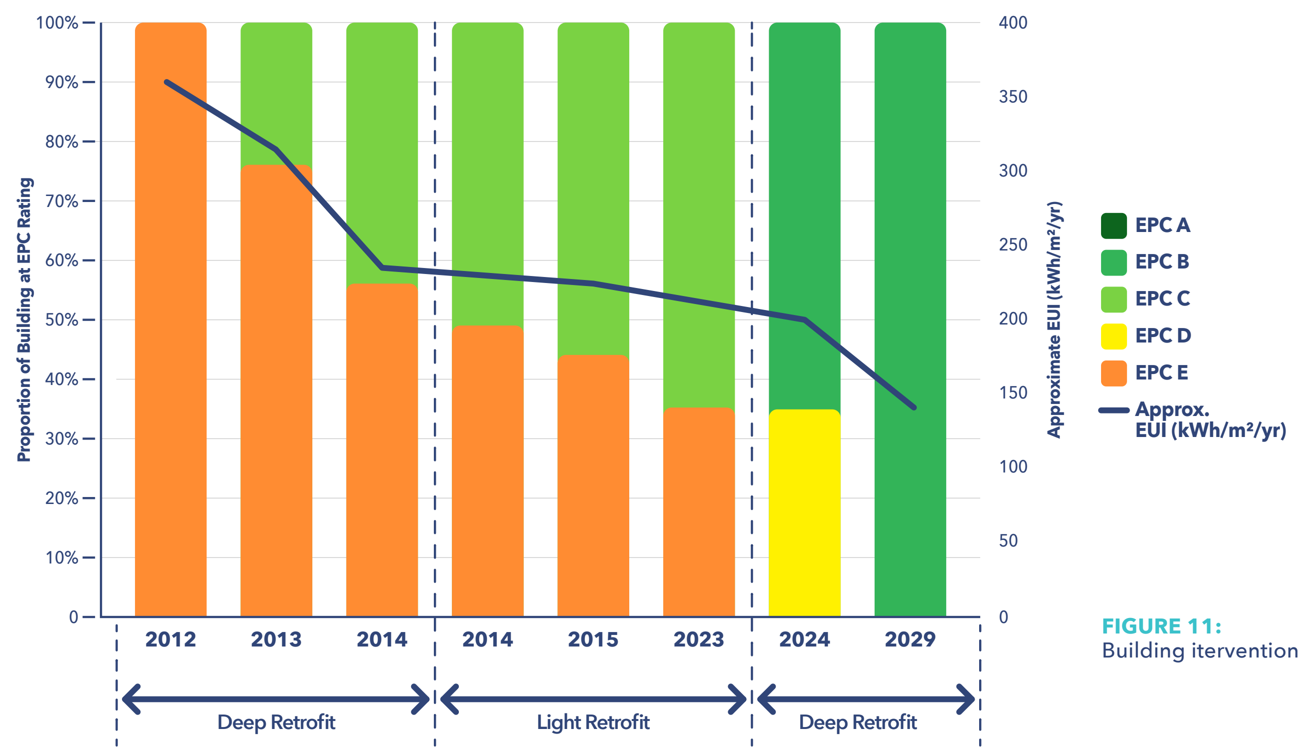


FIGURE 11: Building itervention timeline.

Minerva House
London

Minerva House is an existing 6-storey office building located near London Bridge, opposite Southwark Cathedral. It was originally constructed in 1983.

To reduce the embodied carbon impact, the retrofit strategy aimed to maintain as much of the existing structure and façade as possible, whilst also providing the additional value required to inform the commercial viability of the scheme through increased lettable area.

The building will also be fully electrified, and no fossil fuel use is proposed. It will be mechanically ventilated with heat recovery in place to reduce energy demand. The heating and cooling demands of the building will be met by highly-efficient modular Variable Refrigerant Flow (VRF) systems installed in accordance with BCO guidance for zoning.

Through careful planning, 75% of the existing structure (by volume) will be retained, with 25% demolished to make way for a new extension structure. The existing structure comprises 55% of the overall proposed building structure volume.

A 57% reduction in EUI is also achieved through a deep retrofit the building. This is, in part, due to a proportion of the existing fabric being removed and replaced with a new system which will increase the air tightness and thermal performance of the building. The retained façade will also be insulated, and the glazing replaced to ensure the thermal performance is improved.

PROJECT OVERVIEW

Office Typology: **T2** – Constructed 1980's

Location: London

Type of Retrofit: Deep

Partners:
Client: GPE
Architect: Ben Adams Architects
MEP Consultant: Hoare Lea
Structural Engineer: Heyne Tillett Steel (HTS)
Project Manager: Opera
Cost Consultant: Gardiner & Theobold (G&T)
Main Contractor: Multiplex and Morrisroe
Planning Consultant: DP9

Design Status: Design

Expected Completion: Q3 2026

Project Size: Refurbished Building Area = 18,781 GFAm²

PROJECT ACHIEVEMENTS

- EUI reduction from 210 kWh/m²/yr to 90 kWh/m²/yr
- From EPC C to A
- BREEAM Outstanding
- NABERS 5*

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

Climate Change Adaption

Nature

Embodied Carbon of Minerva House compared to the RIBA targets

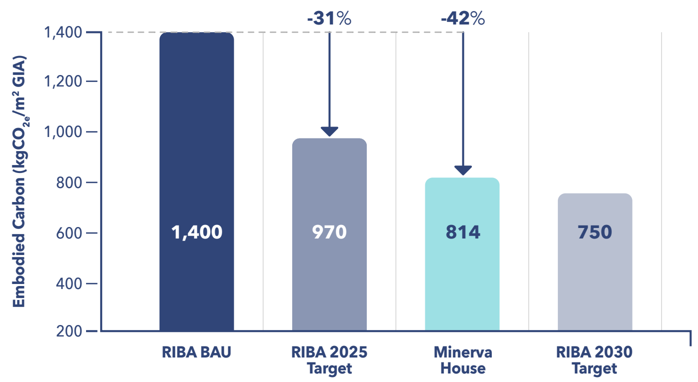


FIGURE 12:
Embodied carbon of Minerva Baseline compared to the RIBA 2025 target (RIBA Lifecycle stages A1-A5, B1-B5, and C1-C4).

Operational Energy Performance of Minerva House against industry benchmarks

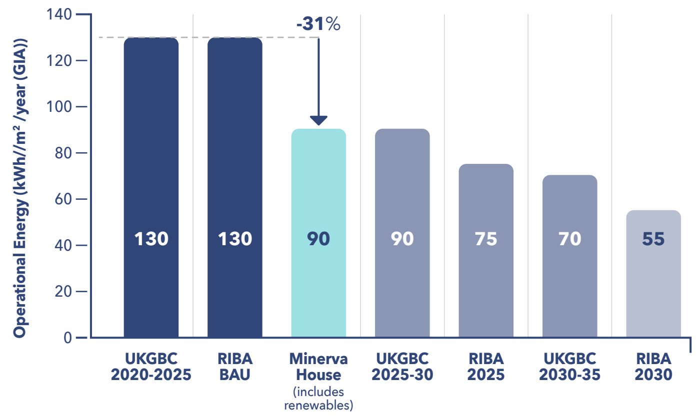


FIGURE 13:
Comparison of Minerva House operational energy performance against industry benchmarks for operational energy.

Havelock
Manchester

Havelock was originally built in 2001 in Manchester's Conference Quarter near to the site of the Hacienda nightclub. Over a decade later, the existing office is now undergoing a major retrofit to bring the building up to modern sustainability standards.

The existing single occupier vacated the property in 2021 which provided a clear opportunity for a building upgrade. The building envelope and original services were beyond their useful lifespan and would have struggled to attract occupiers who are financially secure and creditworthy. This, coupled with the uncertainty over upcoming EPC requirements for commercial letting, shifting market expectations, and the client's own net zero ambition, helped to define the level of retrofit proposed.

To establish the building upgrade strategy, a whole life carbon options appraisal was undertaken which considered a number of scenarios – from a light retrofit to a complete demolition and rebuild. This analysis shaped the project brief, ultimately resulting in the deep retrofit and repositioning of the asset, as opposed to more whole life carbon intensive outcomes (as shown in figure 14).

Operational energy and embodied carbon savings will be achieved through the retention of the existing frame and foundations, as well as an optimised façade design that balances daylight, thermal performance and solar control. Automating building systems and controls and good building management practices are also crucial in achieving the energy and carbon savings. The provision of systems that enable insight and interrogation of building performance will allow for ongoing improvements to be made.

PROJECT OVERVIEW

Office Typology: **T2** – Constructed 2002-2011

Location: Manchester

Type of Retrofit: Deep

Partners:
Client: Credit Suisse Asset Management (CSAM)
Development Manager: Simten
Project and Design Management: Savills
Architect: OMI
Quantity Surveyor: G&T
Contractor: Gilbert Ash
Structures: DP2
M&E: Marketaylor
Energy, Carbon & NABERS UK: Savills Earth
BREEAM: Element Sustainability

Design Status: Construction

Expected Completion: Q2 2024

Project Size: ~ 14,000 m² GIA

PROJECT ACHIEVEMENTS

- ☑ EUI reduction from 174 kWh/m²/yr – 72 kWh/m²/yr
- ☑ From EPC D to A
- ☑ BREEAM Outstanding
- ☑ NABERS 5*

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

Resource Use

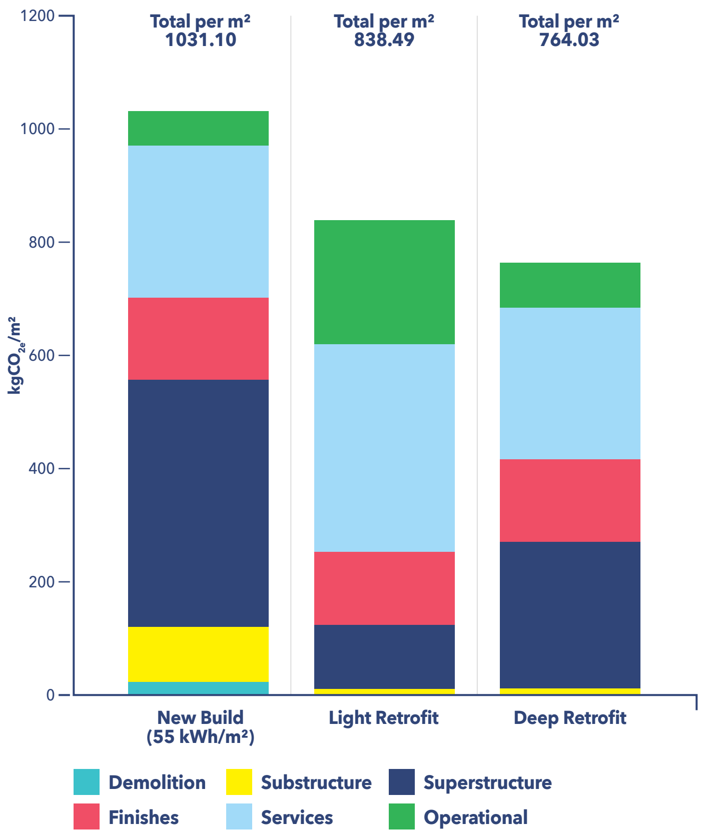


FIGURE 14: Whole life carbon comparison for various retrofit measures.

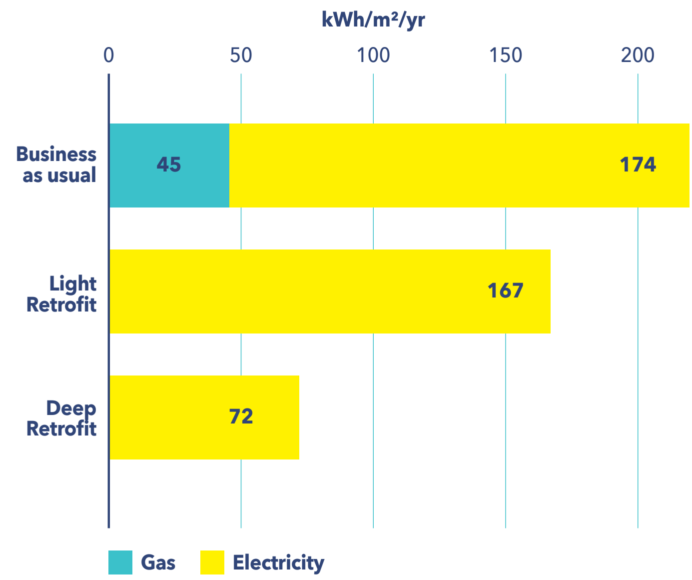


FIGURE 15: Operational energy use comparison for various retrofit routes.

The Entopia Building
Cambridge

The Entopia Building project is an internationally-leading, fabric-first sustainable retrofit of a 1930s, five-storey concrete frame structure with a basement. It is located in a local conservation area in historic Cambridge city centre.

The project goals were to achieve a 'deep green' retrofit that maximised operational utility, value, and energy efficiency and minimised adverse embodied carbon impacts, while pursuing opportunities for holistic sustainability and resilience.

A fabric-first approach was taken in the design strategy to fulfil the EnerPHit standard. This meant prioritising the reduction of energy demand over obtaining energy from more sustainable sources and before designing the building services. The building is on track to use 15% of the energy consumed by the building pre-retrofit which is estimated to achieve cost savings of £1.5m over the first 15 years.

A range of reclaimed and used materials were procured and used in various applications such as the PV rooftop canopy, internal lighting and furniture, fixtures, and equipment (FF&E). This enabled the project to significantly reduce whole life embodied carbon, saving over 21,000 kg of CO_{2e}.

PROJECT OVERVIEW

Office Typology: **T1** – Heritage building constructed pre-1954

Location: Cambridge

Type of Retrofit: Deep

Partners: Client: University of Cambridge – Institute for Sustainability Leadership (CISL)
RIBA Stage 1-3 Architect: Architype
MEP, Acoustics, Sustainability: BDP
Project Manager: 3PM
RIBA Stage 4 onwards Contractor: ISG
Architect: Feilden and Mawson
MEP: Max Fordham,
Structural Engineer: CAR

Design Status: In use

Completed: 2022

Project Size: 2,985m² GFA

PROJECT ACHIEVEMENTS

- EUI reduction from 373 kWh/m²/yr – 58 kWh/m²/yr (including on-site generation)
- BREEAM Outstanding
- EnerPHit
- WELL Gold

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY ALSO EXPLORES:

Resource Use

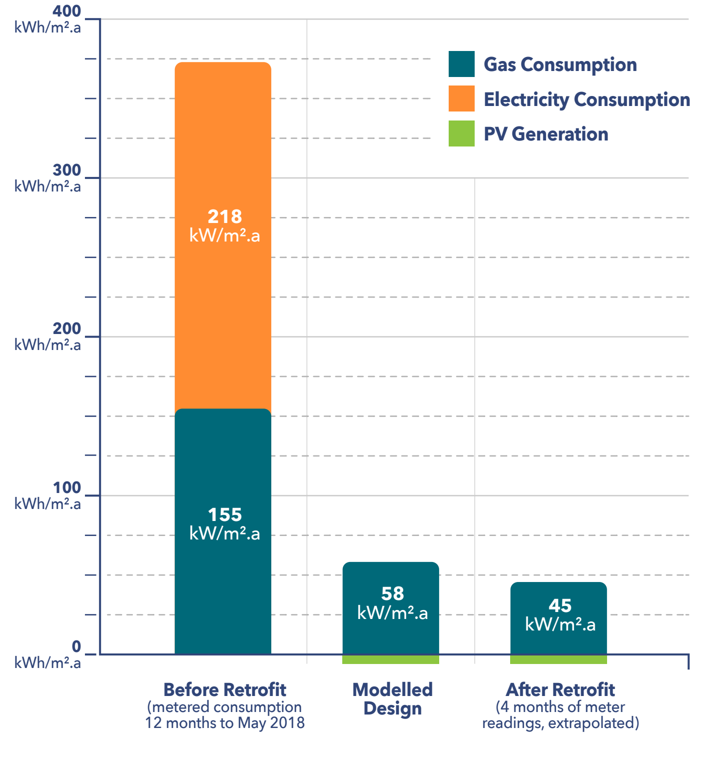
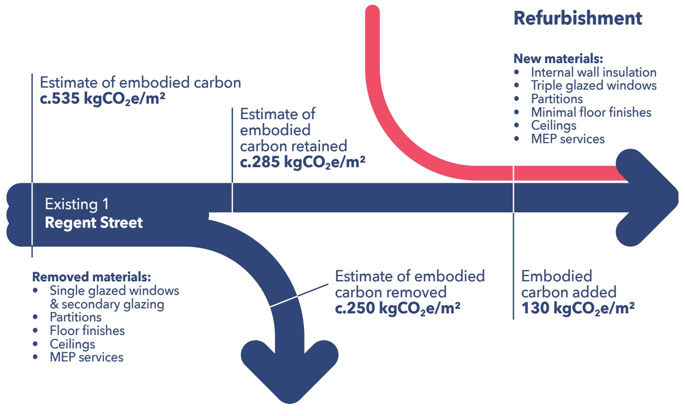


FIGURE 16:
Pre-retrofit, modelled and post retrofit Energy Use Intensity of The Entopia Building.



Note: Embodied carbon figures are of building life cycle Stages A1-A5. Figures for Entopia and LETI targets include substructure, superstructure, internal finishes and MEP. Figures for Entopia are from Stage 5 design (May 22).

FIGURE 17:
Embodied Carbon of The Entopia Building.

Coal House
Cardiff

Coal House is a four-story office building located in Cardiff city centre. It was purpose-built around 1990 and has been occupied by a single tenant until it was vacated in 2022.

Vacant posession of the property presented an opportuny to retrofit the building to maxinimse sustanability and improve user wellbeing. Each retrofit measure throughout the project had to be pursued within the bounds of the project economics and local market value in Cardiff, which is significantly lower then London.

To minimise the embodied carbon impact, the structure was maintained and, instead, the building underwent an exterior refurbishment with solar PV and solar shading installed. The core plant and all heating and ventilation equipment were replaced. Alongside this, technologically intergrated variable air flow valves were included which enabled automated air quality management on a localised basis. The lighting was upgraded to new, highly-efficient LED systems.

To support the ongoing running of the building, a new building management system (BMS) was installed, integrating a smart building server, sensors, access and visitor management systems. Furthermore, a building app Coalhouse.life was introduced to facilitate interaction between the smart technology, building amenity and the building occupants.

Had the required level of investment not been committed, the asset was at risk of becoming a stranded asset, but it now makes a strong and positive impact on the users and the streetscape along a key route through Cardiff city centre, thereby contributing to broader social value.

PROJECT OVERVIEW

Office Typology: **T3** - Constructed 1985-2001
Location: Cardiff
Type of Retrofit: Deep
Partners: **Client:** Create Real Estate
Project Manager: Mapp
Architect (feasibility): Stride Treglown
M&E Consultant: SVMA
Contractor: Oktra
Sustainability Consultant: Low Carbon Alliance
Design Status: In use
Completed: March 2023
Project Size: 30,000sqft NIA

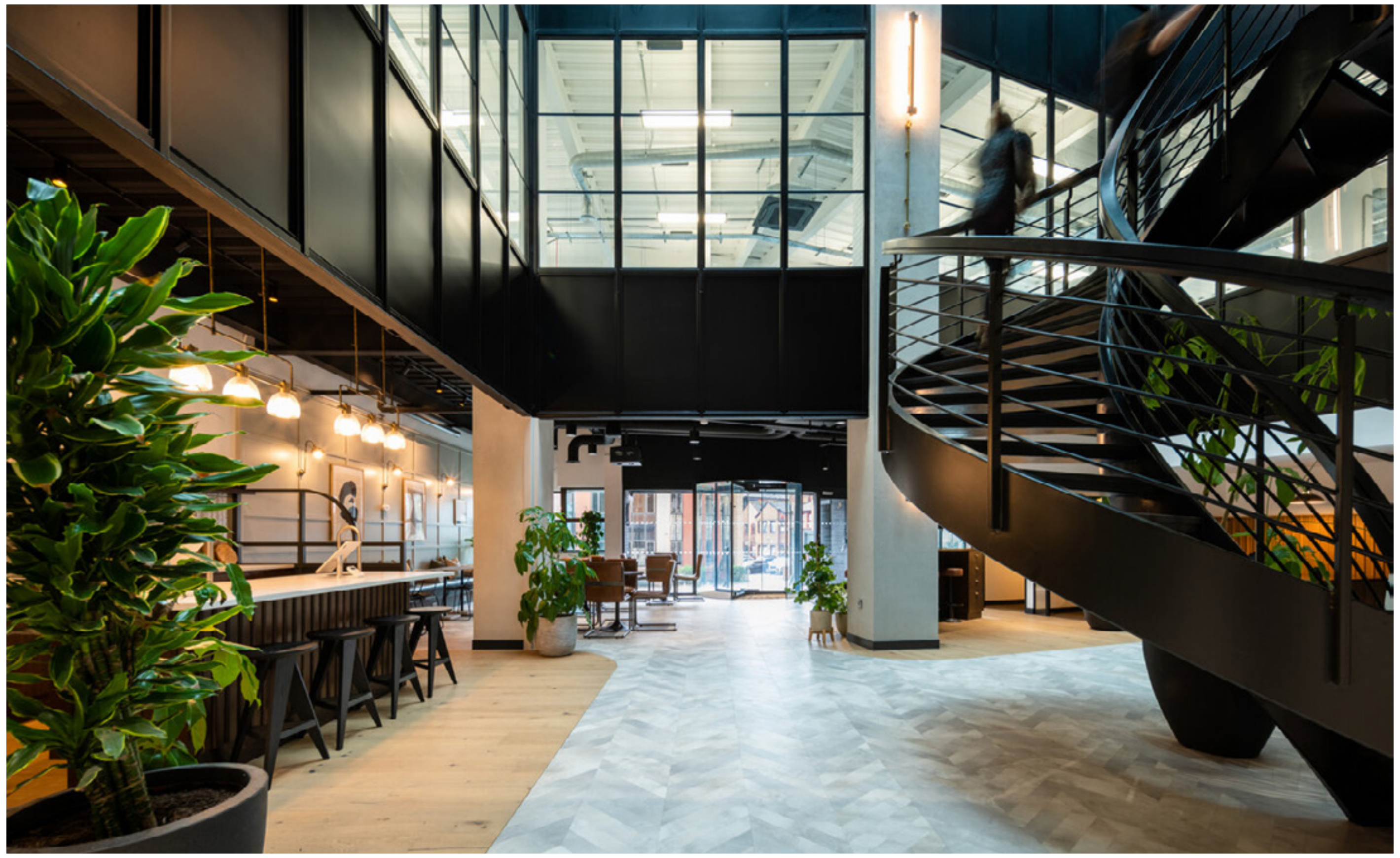
PROJECT ACHIEVEMENTS

- From EPC D to A
- BREEAM Excellent
- SKA Gold
- Fitwel 2 stars
- AirScore UK Platinum rating
- Rental increase from £16.75psf to £25psf
- WiredScore Platinum

SEE CASE STUDY LIBRARY
for more information here...

THIS CASE STUDY WILL ALSO EXPLORE:

In-use energy data once it is available



10 APPENDICES

10.1 KEY METRICS USED TO EVALUATE IMPACT

In 2024, the UK Net Zero Carbon Buildings Standard (NZCB Standard) is due to set out standards against which buildings will be evaluated to determine whether they can be verified as 'net zero carbon' buildings. This cross-industry initiative builds on UKGBC's Net Zero Carbon Buildings Framework Definition, as well as subsequent guidance by UKGBC and other leading organisations and networks, to reach consensus around the key principles for defining net zero for different building types. These key principles are expected to set operational energy performance, upfront embodied carbon, and whole life carbon limits for different building typologies.

ENERGY PERFORMANCE TARGETS

UKGBC's Net Zero Carbon: Energy Performance Targets for Offices set out performance targets for Whole building, Base building, and Tenant energy use, that aimed to align with the energy demand reduction trajectory required for the UK's economy to be fully powered by zero carbon energy by 2050. These targets are set out in Table 8 below. Interim targets illustrate how building performance is expected to advance over time.

There is now broad industry consensus over the trajectory required for office buildings so it is anticipated the performance targets set by the NZCB Standard will relate strongly to those set out here.

Energy performance targets are the key metric used in this study to measure retrofit impact, however, as we move towards an electricity grid powered by renewable energy, reducing energy consumption at peak times also is critical to enable the decarbonisation of the grid, as described in wider consideration 15: Supporting the Overarching Retrofit Strategy's transition to a net zero carbon electricity system.

TABLE 8:
Energy performance targets for buildings targeting net zero carbon for operational energy.

		INTERIM TARGETS			PARIS PROOF TARGET
SCOPE	**METRIC**	**2020-2025**	**2025-2030**	**2030-2035**	**2035-2050**
Whole Building Energy	kWh_e/m^2 (NLA) / year	160	115	90	70
	kWh_e/m^2 (GIA) / year	130	90	70	55
	DEC Rating	D90	C65	B50	B40
Base Building Energy	kWh_e/m^2 (NLA) / year	90	70	55	70
		70	55	45	55
		4.5	5	5.5	B40
Tenant Energy		70	45	35	35

NLA = Net Lettable Area | **GIA** = Gross Internal Area

ENERGY PERFORMANCE CERTIFICATES (EPCS) AND ENERGY PERFORMANCE-BASED RATINGS

EPCs are a widely used indicator that have an impact on value as well as compliance. They are the key regulatory driver of the energy performance of even large commercial office buildings, although it is widely acknowledged that they do not necessarily reflect energy performance in use. In the absence of a mandatory performance-based rating system for commercial buildings over 1000sqm, such as that proposed by Government in its 2021 consultation, many asset owners therefore focus on improving EPC ratings rather than energy performance. EPCs should be regarded as a proxy measure only however, with potential future legislation and market drivers from the growth of corporate net zero commitments and initiatives like NABERS UK, commercial buildings will increasingly need to move towards a performance-based rating system.

UPFRONT EMBODIED CARBON AND WHOLE LIFE CARBON

While there is growing consensus around upfront embodied carbon benchmarks and limits for new buildings, retrofit is inherently more complex given the high number of variables around both the scope of retrofit (light to deep), and the extent to which retrofit interventions form an essential part of maintenance and replacement cycles. The NZCB Standard currently defines retrofit as "where more than 25% of the building envelope undergoes renovation, or a substantial replacement of building services occurs. For intensive refurb projects where more than 50% of the existing slab area is demolished, the building will be classed as new build" [22].

There is ongoing debate around the environmental and social benefits of reusing existing buildings, with whole life carbon assessments being used to demonstrate the whole life carbon savings of retrofit, as compared to demolition and rebuild like-for-like [23]. There are inherent embodied carbon savings achievable through the reuse of structural elements, as an average of 65% of a typical office building's embodied carbon can be attributed to the substructure and superstructure of a typical commercial office [24]. The embodied carbon of deep retrofit projects can still be high however, especially when significant services upgrades and/or facade replacement works are undertaken, so it is essential to measure embodied carbon with the aim of reducing the carbon impacts over the whole lifecycle of the building. Recent research by CRREM found the 'carbon payback' of deep retrofits of commercial buildings to be under 8 years, even when taking grid decarbonisation into account, while light retrofit payback periods could be below 3 years [21].

Comprehensive embodied carbon data can still be very difficult to obtain for all products and materials, however measuring the relative embodied carbon of different interventions is a useful decision-making tool, particularly when prioritising, or phasing retrofit measures, or specifying materials, as there can be significant variations in the embodied carbon of otherwise similar materials or products, or even between different suppliers or manufacturers. Manufacturers and suppliers can support the decision-making process by providing accurate, transparent, and consistent data.

The approach chosen for this report reflects the lack of clear embodied carbon data available and the range of values attributed to different materials and products, thus following a simple 'traffic light' Red-Amber-Green (RAG) rating methodology. This approach emphasises where greater caution is needed to ensure upfront carbon 'costs' are fully considered as part of an overall strategy. The RAG categories indicate the upfront embodied carbon of a retrofit measure, relative to whole life operational carbon savings observed within this report, given the measure's anticipated lifespan. These indicators have only been used to create a distinction only and flag where greater caution may be needed, they are not intended to indicate whether a retrofit measure should, or should not be implemented, as every strategy is contextual, depends on building specifics, and in many cases upgrades will need to be carried out as part of standard maintenance and replacement cycles. As noted previously, carbon payback should only be used as part of a more nuanced approach that takes into account the role buildings must play in achieving a net zero electricity system:

Relative Embodied Carbon Impact

upfront embodied carbon is...

Red	>100%
Amber	50-100%
Green	<50%

...of whole-life operational carbon savings

10.2 METHODOLOGY

DATA TEMPLATE

To gather live project data from the Task Group we used a Data Template that allowed organisations to communicate key building information (location, floor area and number of stories etc.) and any significant variables that could affect the results, while retaining overall anonymity. Comprehensiveness of datasets varied; 25 datasets were received, 19 of which were comprehensive datasets, with each age category including at least four good datasets that gave insight into the impact of different retrofit measures. Where data was drawn from design stage projects, energy modelling was carried out by project teams using a range of different techniques, including IES and Excel.

The Template requested data around historic energy consumption, baselines of gas and electricity consumption, base building and tenant energy consumption, and EPC ratings. The modelled impacts of different retrofit measures were then recorded according to the type: fabric, building services, or renewables and whether they could be implemented during optimisation, light retrofit or deep retrofit. Embodied carbon and cost data was also requested, however where details were missing, the Task Group made assumptions based on their understanding and experience.

Datasets across each age category were normalised and combined to allow comparison, and an initial overview produced to illustrate the average (mean) impact per retrofit measure, and the range of variation found within the datasets.

We analysed the impact of each retrofit measure on the baseline EUI, establishing both the mean and range in terms of percentage reduction.

MODELLED DATA VS REAL WORLD DATA

There are some known issues with building models as they can include assumptions that do not accurately reflect the reality of building operation. Furthermore, models are generally created at early design stages to guide overall energy strategies, but then not updated to reflect design development or construction on site. Many of the datasets used in our analyses were based on TM54 Evaluating operational energy use at the design stage (2022) | CIBSE which are considered more accurate, however results illustrated here can only be considered as indicative of potential outcomes and should not be used to directly inform business decisions.

We explored basing this study on anonymised in-use data, however data for retrofitted projects is not widely available even to building owners and occupiers. Where data is available it does not generally allow like-for-like comparison with baseline data; as often pre-retrofit data is unavailable, but importantly for the purposes of this study, the occupancy shifts that have taken place since COVID-19, would have significantly skewed energy consumption rates.

10.3 EPC IMPACTS

Impact of each measure on EPC rating numerical score:

EPC Impact Scores	
Low	0-5
Medium	5-15
High	15+

The EPC impact estimations below are based on the experience of Task Group members and the professional consultants they work with on commercial office projects. The impacts relate to the EPC methodology introduced in June 2022, however, are intended to be a 'rule of thumb' guide only. EPC impact will always depend on the starting point on the EPC rating and the specific building characteristics.

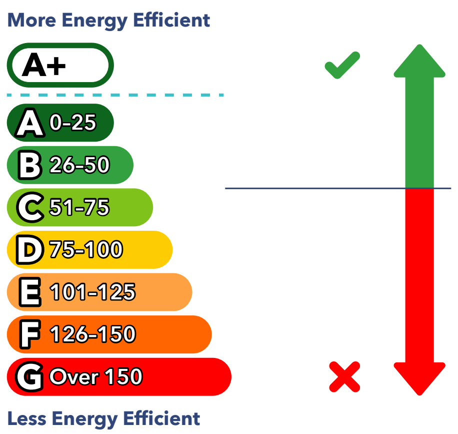


FIGURE 18:
EPC rating scores and thresholds, and anticipated MEES threshold in 2030.

MEASURES	EPC IMPACT (H/M/L)			NOTES
Fabric	**Age Category 1** (Heritage -1964)	**Age Category 2** (1964 - 1984)	**Age Category 3 & 4** (1984 - 2011)	
Floor Insulation	L	L	L	Pre 1964 fabric impacts might have a medium impact but only if the current performance is extremely poor.
Roof Insulation	L	L	L	
Wall Insulation	M	L	L	
Façade Replacement	L	L	L	
Window Replacement	M	M	M	Impact only significant if glazing is single glazed.
Building Airtightness	M	M	M	Pre 1964 fabric impacts might have a medium impact but only if the current performance is extremely poor.
Solar Film	L	L	L	
External Shading Systems	L	L	L	
Fabric other (please specify details in 'Detailed Description' column)	L	L	L	
M&E				
Boiler Upgrade	M	M	L	Greatness change where existing equipment of poor efficiency and high carbon fuel (e.g., oil).
Chiller Upgrade	L	L	L	Impact could be medium if exising equipment has a particularly poor performance.
Decarbonisation of Heat (ASHP, GSHP etc)	H	H	H	Greatest change where existing equipment of poor efficiency and high carbon fuel (e.g., oil).
Connection to District Heating	L	L	L	Low unless district system has a significantly lower emissions factor than gas (which is rare).
Pump Motor Replacement with High-efficiency, Variable Speed Alternatives.	L	L	L	
MVHR	L	L	L	Could be medium if a mechanical based system and currently no heat recover.

TABLE 9:
Impact of retrofit measures on EPC.

10.4 COST RANGES, ASSUMPTIONS AND EXCLUSIONS

METHODOLOGY

The cost data for this study was extracted from the samples and organised into a comparative table. During this process, we encountered gaps in the available information, instances of pricing without clearly stated assumptions, and other anomalies that necessitated the exclusion of certain data sets from our analysis. Quality checks were subsequently conducted on the remaining data. To ensure comparability, the data was normalised by removing outliers—confirmed through standard deviation analysis for each metric—before adjusting for both location and time variables. This harmonised data was then benchmarked against recent projects undertaken by Task Group members Arcadis and Torridon to provide a frame of reference.

COST SCHEDULE (PART 1)

MEASURES	TYPICAL COST RANGE (£/M² GIA)		BASIS	KEY COST DRIVERS (NOT EXHAUSTIVE)
	Lower	Upper		
ASHP for DHW	£10	£20	Connection to existing system.	Capacity of system.
BMS Health Check	£1	£3	Upgrade of head end and system integration; assumes BMS already installed.	Number of points, age/condition of system.
BMS Replacement	20	50	Cost range will vary depending on equipment and number of points.	Number of points and controllability.
Boiler Upgrade	£4	£12	Connection to existing heating system; cost for T 1&2 assumes load requirement is reduced through other retrofit measures.	Capacity of system; level of insulation and airtightness of building.
Building Airtightness	£2	£10	Replacing gaskets and sealing around doors and windows. Excludes removaland testing.	Age of building, number of windows/doors.
CO_2 Ventillation Control	£2	£10	Connection to existing system.	Level of control required.
Connection to District Heating	£8	£14	Connection to existing system.	Distance from plant room to system.
Decarbonisation of Heat (ASHP, GSHP etc)	£50	£220	ASHP/GSHP as alternative form of heating/cooling with connection to existing system is compatible.	Compatibility with existing system, type of system installed (i.e. GSHP requires excavation/piling or similar, and linking this with other external works can potentially reduce the cost of installation).
Façade Replacement	£640*	and above	Assumes building has existing cladding which will be removed, and that no improvement works are required to the existing structure and secondary supporting system. Assumes the building is vacant when works are carried out and there is good access for replacement works to take place. Excludes temporary works, protection, move management etc. Any abnormal planning requirements.	Material specification and complexity of design.
Floor Installation	£6	£10	Assumes rigid insulation fitted above ground floor slab; excludes adjustments of levels, replacement of raised access floor pedestals/ ramped access etc.	Extent of existing insulation and product specification.
HVAC - Upgrade to Existing System	£1	£10	Upgrades to the existing system.	Extent of upgrades (assumed all minor).
Internal Wall Insulation	£20	£60	Adding insulation to internl face of solid external wall witha plasterboard covering.	Wall to floor ratio, ease of retrofitting wall coverings.
Lifts Upgrade	£60	£120	Assumes lifts replaced in existing shaft; costs depend on number of lifts, height of building, number of calling points, finishes etc.	Number of lifts, height of building, number of calling points, finishes etc.

*Refers to £/m2 GIFA, rather than GIA

TABLE 10:
Cost of retrofit measures and associated assumptions.

COST SCHEDULE (PART 2)

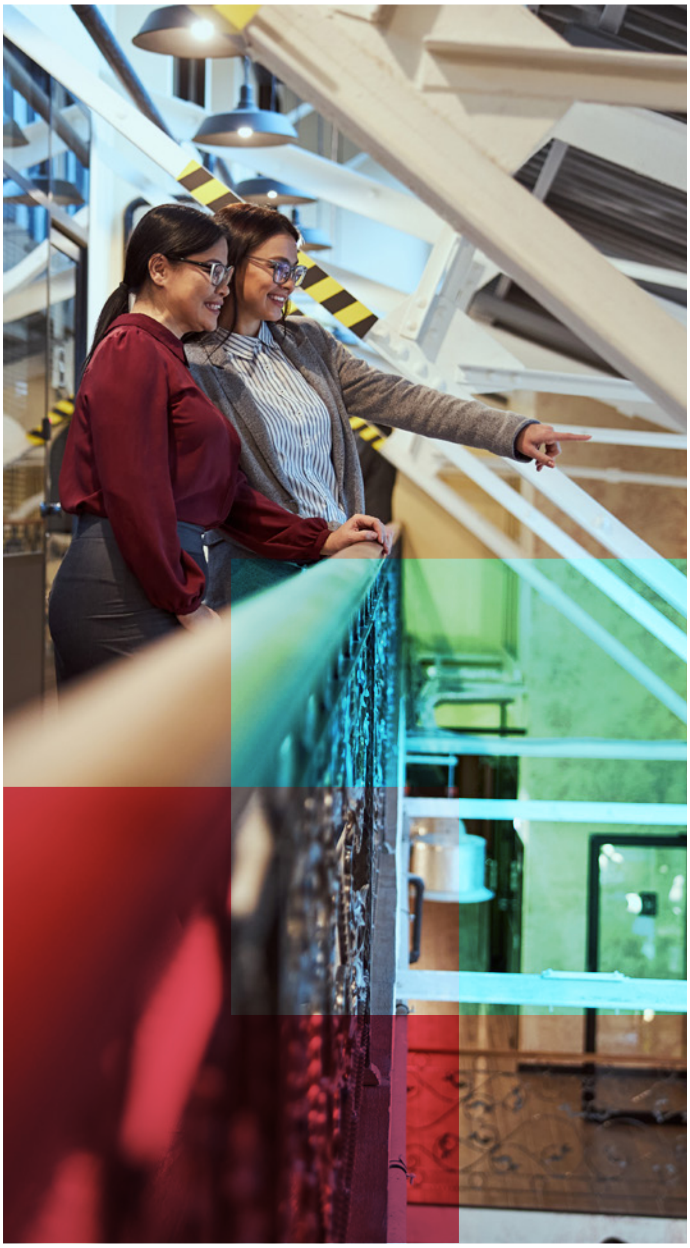
MEASURES	TYPICAL COST RANGE (£/M² GIA)		BASIS	KEY COST DRIVERS (NOT EXHAUSTIVE)
	Lower	Upper		
Lighting Controls	£1	£5	Adding controls to existing lighting system. Excludes finishes.	Level of control required.
Low Energy Lighting	£10	£60	Either replacement of lamps or fittings in existing positions; assumes Cat A installation.	Whether existing lights can be retrofitted, or need to be replaced.
MVHR	£40	£100	Adapt existing system, including additional ductwork.	Ductwork will be driven by building configuration (i.e. heavily cellularised will typically be at the upper end of the cost scale), requirement to form new risers and distribution routes.
Pump Motor Replacement	£2	£5	Replaciement of similar size pumps in existing positions.	Type and age of system.
Reduce Tenant Equipment Loads	Varies		Cost range will vary depending on equipment and extent.	Dependent on equipment and extent.
Roof Insulation	£10	£50	Insulation and basic roof covering to falt roof or insulation to underside of a pitched roof.	Access to roof, type of roof finish; typically insulation to underside will be at the lower end, and overlay systems at the upper end.
Secondary Glazing	£20	£60	New secondary glazing installed internally.	Area of glazing as a proportion of the overall building façade.
Solar Film	£3	£10	Solar film applied to existing glazing and curtain walling.	Area of glazing as a proportion of the overall building façade.
Solar PV	£3	£30	PV panels installed onto flat roof on frame with connection to existing system. Possible installation of battery storage.	Energy output requirements, roof space availability.
Window Replacement	£60	£150	Replacing double glazing in existing window openings; excludes curtain walling.	Area of glazing as a proprtion of the overall building façade; standardisation/consistancy o the size of units, type of windows (i.e. sash and case typically at higher end all other things being equal etc).

TABLE 11:
Cost of retrofit measures and associated assumptions.

ASSUMPTIONS AND EXCLUSIONS FOR INDIVIDUAL RETROFIT MEASURES

General Key Cost Drivers
(applies to all measures)

- Building age, listing status, buildings in conservation areas etc.
- GIFA, and design efficiency metrics such as net to gross, wall to floor ratio, number of floors.
- Extent of works undertaken simultaneously.



Assumptions

- Prices as current day 2Q23.
- Works carried out during normal working hours and in sequence.
- Works carried out as part of a wider project.
- Programme optimised to be the most cost effective period.
- Costs relate to the refurbishment of a Cat A office, i.e. excludes tenant fit-out (ie. lighting, ventilation, on-floor heating/cooling).
- Costs generally depend on the level of specification of the building. Cost ranges provided assume mid-range.
- BCIS location factor of 100.

Exclusions

- Consequential works connected with the measures, e.g. aesthetic upgrades.
- Temporary works (i.e. removal of existing ceilings to gain access).
- Subcontractor and main contractor preliminaries, OH&P and risk.
- Out of hours and non-productive working.
- Contingency.
- Insurance.
- Finance and interest costs.
- Obstructions and discoveries.
- Deleterious and hazardous materials surveys and investigations.
- VAT.
- Design, professional, planning and building control fees.
- Site investigations and surveys.
- Inflation adjustment up to start on site.
- Future legislation changes.

ASSUMPTIONS AND EXCLUSIONS FOR WORKED EXAMPLE CASE STUDY

Assumptions

- Prices as current day 4Q23.
- Works carried out during normal working hours and in sequence.
- Works are carried out as part of a wider-refurbishment project.
- Programme optimised to be the most cost effective period.
- Costs generally depend on the level of specification of the building. Cost ranges provided assume mid-range.
- Works are competatively tendered.
- Building is vacant.

Inclusions in pricing

- Lighting: luminaries, controls and cabling back to an existing on-floor distribution board. New containment excluded.
- ASHP: air source heat pump plus vertical pipework. Assumes it is replaced within an existing plant enclosure with existing power connections.
- Mixed-mode (automatic opening windows): includes BMS point, power and actuator. Assumes 50% of windows are automatic opening. Excludes BMS system replacement or upgrade.
- MVHR (replace AHU with heat recovery): Replace main plant and vertical ductwork in existing locations. Assumes replaced within an existing plant enclosure with existing power connections.
- PV: panels + frame and cabling back to an inverter. Excludes battery storage.
- BMS: landlord system change. Excludes any consequential works to enable this to take place.

Exclusions

- Consequential works connected with the measures, e.g. aesthetic upgrades.
- Temporary works (i.e. removal of existing ceilings to gain access).
- Subcontractor and main contractor preliminaries, OH&P and risk.
- Out of hours and non-productive working.
- Contingency.
- Insurance.
- Finance and interest costs.
- Obstructions and discoveries.
- Deleterious and hazardous materials surveys and investigations.
- VAT.
- Design, professional, planning and building control fees.
- Site investigations and surveys.
- Inflation adjustment up to start on site.
- Upgrades to meet any deficiencies when assessed against current regulations.
- Future legislation changes.
- Strip out.
- Structural works.
- Reconfiguration of spaces.
- Finishes.
- Public health system.
- On-floor MEP other than lighting.
- Smoke ventilation system.
- Extract to WCs and showers.
- Sprinklers.
- Fire alarm.
- Electrical other than lighting.
- AV/IT.
- Comms.
- Security.
- BMU.
- Lifts.

10.5 DETAILED EMBODIED CARBON METHODOLOGY

BALANCING WHOLE LIFE CARBON WITH IN-USE ENERGY PERFORMANCE

Verco carried out a high level assessment of the materiality of embodied carbon emissions compared with operational carbon savings for retrofit measures, which highlighted the need to take a whole life carbon perspective and consider the relevant counterfactual and timing of the refurbishment.

Energy Use Intensity (EUI) limits, as proposed for the NZCB Standard are needed to ensure that the built environment takes no more than its fair share of total UK low carbon supply, but embodied carbon targets are equally important to avoid pushing deep retrofit too far. This could, in certain circumstances, lead to an increase in whole life carbon emissions such as the replacement of carbon intensive fabric measures before they have reached the end of their service life. In this case the project should bear the full embodied carbon of their replacement, rather than the marginal impact compared with a like-for-like replacement of the existing components.

A key limitation of this assessment is the level of uncertainty regarding the extent and timing of decarbonisation of the main materials used in retrofit measures, compared with the greater certainty associated with grid decarbonisation. Factoring in the decarbonisation pathways published for the various materials reduces the embodied carbon impact for projects delivered in the future compared with those delivered today.

The conclusion to be taken from this is not to do nothing and wait for the grid and material to decarbonise but make the most of the structures and components already in place and the next opportunity for end-of-life replacements, specifying the best option from a whole life carbon perspective. Completing Whole Life Carbon (WLC) assessments can support understanding of the carbon cost and benefit from certain measures and help stakeholders make informed decisions.

EMBODIED CARBON METHODOLOGY

1. **Rating**
   The red, amber, green (RAG) embodied carbon rating used in this methodology is based on the embodied carbon payback (EC PB) and the expected lifetime of the equipment needed for the measure. If the EC PB is less than 50% of the expected lifetime, then the measure was assigned a "green" rating. If it is between 50% to 100% then it is rated "amber". Lastly if the EC PB exceeds the expected lifetime, then it is rated "red".
2. **The Data**
   The data has been extracted from multiple audits performed by Verco in the UK. The average EC PB is then taken for measures of the same type, for example replacing a boiler with a heat pump.
3. **Operational carbon**
   The operational carbon savings from a measure is calculated based on the energy saving and CRREM. v2 carbon factor and UK GHG conversion factors for electricity and gas respectively.

   It should be noted that fabric measures are usually recommended after heat decarbonisation and are assumed to be delivered between 2040-2050 due to their high lifetime and high cost. This has a negative effect on the operational carbon saving of fabric measures, due to the CRREM carbon factor decreasing with time as the grid decarbonizes and as we have not factored in any equivalent decarbonisation of the material.
4. **Embodied carbon**
   The embodied carbon for a measure is calculated either for a particular piece of equipment e.g. upgrading the AHU with one with heat recovery, or on a per square meter basis e.g. the EC associated per square meter of PV panels. Lastly it can be a mixture of both e.g. for HVAC upgrades with new piping and equipment.

10.6 OVERVIEW OF BUILDING AGE CATEGORIES

Building Type 1
Heritage pre-1964

Heritage buildings constructed pre-1964 were typically constructed from traditional materials such as stone or brick, forming solid load-bearing walls with no insulation. Poor air tightness is common due to draft and air leakage throughout the building envelope. Large areas of single glazing often feature which lack the energy efficiency and low emissivity coating of modern glazing systems. Originally, technologies such as gas-fired boilers were installed for heating and domestic hot water, however, cooling systems were not utilised, and buildings typically relied on natural ventilation throughout.

Retrofitting heritage buildings comes with particular challenges due to the inherent uncertainties around the existing fabric, and potentially stringent planning restrictions, particularly where buildings are listed or are within a conservation area.

Building Type 2
1964 – 1984

Buildings constructed during the period 1964-84 typically utilised a steel or reinforced/in-situ concrete frame with no insulation. Where insulation was installed, this tended to be of poor quality and risks containing dangerous substances such as asbestos. A large variety of materials were used for facades such as brick, steel, aluminium and reinforced concrete, with highly glazed areas to maximise daylight gains. However, the use of single glazing is highly energy inefficient, particularly during winter and often leads to user discomfort in summer due to overheating. Cooling systems were not originally designed within these buildings, and they rely on natural ventilation through operable windows. Heating and domestic hot water systems were powered by gas-fired boilers which are highly inefficient compared to modern standards.

Replacing the building fabric of buildings from this era is often considered challenging due to limited wall cavities and the risk of exposure to harmful building materials. Façade modifications should be carefully considered to ensure the architectural integrity of the building is maintained whilst increasing energy efficiency.

Building Type 3
1985 – 2001

Buildings constructed during the period 1985-2001 were typically formed from steel or reinforced concrete frames with moderately improved insulation. Although heating and domestic hot water were still generally powered by gas-fired boilers, HVAC systems had better zoning capabilities and controls which reduced energy consumption and improved comfort. Many buildings implemented variable air volume (VAV) systems, to allow for more precise control over temperature regulation and airflow. Some buildings also incorporated energy recovery ventilation systems which reuse waste heat to condition fresh air. Double-glazed windows were often installed which reduced heat loss compared to single glazing. Buildings constructed post-1995 also paid greater attention to reducing thermal bridging around openings, in part due to new building regulation specifications.

Although moderate improvements to the performance were achieved in many of the buildings constructed between 1985-2001, the materials and systems were still of relatively poor quality compared to modern standards.

Building Type 4
2002 – 2011

Buildings constructed during the period 2002-2011 typically utilised steel or reinforced concrete frames with improved insulation materials and techniques. Although providing heating through gas-fired boilers was still commonplace, variable refrigerant flow (VRF) HVAC systems were implemented to improve energy efficiency. Domestic Hot Water (DHW) was often electrified, and point-of-use (POU) heaters were utilised to reduce heat loss. More advanced double-glazed windows were installed which had low-emissivity coatings and improved thermal properties to reduce heat transfer. Building regulations also encouraged efforts to reduce thermal bridging and gaps in insulation within elements of fabric at joins or openings.

12 REFERENCES

[1] **UK Green Building Council**
Net Zero Whole Life Carbon Roadmap
November 2021. [Online].

[2] **McKinsey & Company**
Call for action: Seizing the Decarbonization Opportunity in Construction
July 2021. [Online].

[3] **CRREM**
Report No. 3: Retrofit Harmonisation Roadmap
May 2020. [Online].
Available: https://www.mckinsey.com/industries/eAvailable: https://www.crrem.eu/report-no-3-retrofit-harmonisation-roadmap/.

[4] **UK Government**
The Non-Domestic National Energy Efficiency Data-Framework 2022 (England and Wales)
June 2022. [Online].

[5] **UK Government**
Introducing a Performance-Based Policy Framework in large Commercial and Industrial Buildings in England and Wales
March 2021. [Online].

[6] **IEA**
Renovation of Near 20% of Existing Building Stock to Zero-Carbon-Ready by 2030 is Ambitious but Necessary
September 2022. [Online].

[7] **JLL**
Retrofitting Buildings Essential to Reduce Energy Costs and Combat the Global Energy Crisis
November 2022. [Online].

[8] **Savills**
New MEES Standards in Offices: Let's Not Forget Why Better Energy Efficiency is Good for All of Us
March 2023. [Online].

[9] **Turner & Townsend Alinea, Arup, Capital Real Estate Partners**
What the Government's Commercial Non-Domestic EPC B Pledge Means for Real Estate
March 2023. [Online].

[10] **Savills**
Spotlight: European Office Occupancy
March 2023. [Online].

[11] **BCO**
BCO Guide to Specification Key Criteria
February 2023. [Online].

[12] **J. Chen**
Flight to Quality: What it is, How it Works
April 2022. [Online].

[13] **JLL**
Real Estate's Flight to Quality is Bringing Investors and Occupiers Closer
March 2023. [Online].

[14] **The Times**
Empty office space on the rise after Covid
April 2023. [Online].

[15] **London Property Alliance**
Retrofit First, Not Retrofit Only: A focus on the retrofit and redevelopment of 20th century buildings
[Online].

[16] **Urban Land Institute**
Breaking the Value Deadlock: Enabling Action on Decarbonisation
October 2022. [Online].

[17] **RICS**
Sustainability and ESG in Commercial Property Valuation and Strategic Advice (3rd Edition)
May 2023. [Online].

[18] **S. M. Hossain, J. van de Wetering, S. Devaney and S. Sayce**
UK Commercial Real Estate Valuation Practice: Does it Now Build in Sustainability Considerations?
June 2023. [Online].

[19] **UKGBC**
A Guide for Delivering Social Value on Built Environment Projects
March 2022. [Online].

[20] **LETI**
Operational Carbon in Whole Life Carbon Assesments
February 2023. [Online].

[21] **CRREM**
EMBODIED CARBON OF RETROFITS: Ensuring the Ecological Payback of Energetic Retrofits
September 2023. [Online].

[22] **UK Net Zero Carbon Buildings Standard**
UK Net Zero Carbon Buildings Standard Technical Update & Consultation
June 2023. [Online].

[23] **LETI**
LETI Unpicket: Retrofit vs Rebuild
March 2023. [Online].

[24] **LETI**
Embodied Carbon Primer
January 2020. [Online].

The voice of our sustainable
built environment

UK GREEN BUILDING COUNCIL
THE BUILDING CENTRE
26 STORE STREET
LONDON WC1E 7BT

INFO@UKGBC.ORG

UK Green Building Council
ukgbc.org

ADVANCING
NET ZERO

COMPANY REGISTRATION NUMBER 01029239
CHARITY REGISTRATION NUMBER 1135153