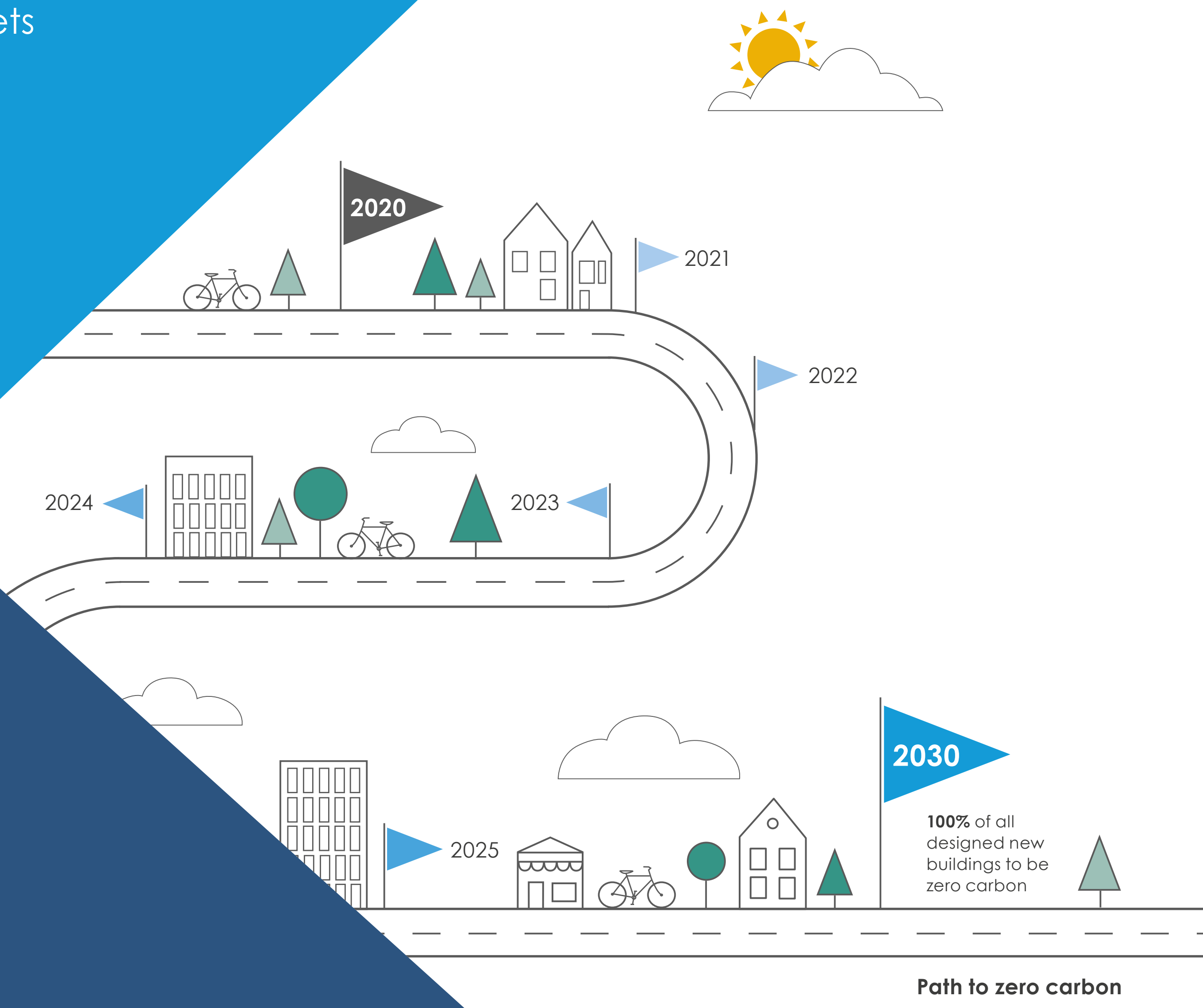
LETI Climate Emergency Design Guide

How new buildings can meet UK climate change targets



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With thanks to all who contributed to this guide:

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About LETI

The London Energy Transformation Initiative (LETI) was established in 2017 to support the transition of the capital's built environment to net zero carbon, providing guidance that can be applied to the rest of the United Kingdom (UK).

We do this by:

→ **Engaging with stakeholders** to develop a robust and rapid energy reduction approach, producing effective solutions to the energy trilemma of security, sustainability, and affordability;

→ **Working with local authorities** to create practicable policy alterations to ensure the regulatory system is fit for purpose, placing verified performance at its core;

→ **Encouraging and enabling collaboration** within a large, diverse group of built environment professionals; and

→ **Providing technical advice to support exemplar developments,** enabling leader who want to deliver net zero carbon buildings.

LETI is a network of over 1,000 built environment professionals who are working together to put London on the path to a zero carbon future. The voluntary group is made up of dedicated and passionate developers, engineers, housing association professionals, architects, planners, academics, sustainability professionals, contractors, and facilities managers, with support and input provided by the Greater London Authority (GLA) and London boroughs. LETI was established for these groups to work collaboratively to put together evidence-based recommendations for two pieces of policy – the new London Environment Strategy and the rewrite of the London Plan (planning policy guidance published by the GLA). Many of the recommendations that LETI put forward to the GLA have been included in emerging London policy and Energy Assessment Guidance.

Over the last year LETI has focused on providing this guidance on defining what good looks like in the context of the climate emergency for new buildings. This report is the culmination of these efforts. These ideas will inevitably refine and evolve over time.

For more information on LETI, please see:
www.LETI.london

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Foreword

Leading scientists now say that unless we change course drastically, within the lifetime of people alive today, we are heading for a world which can support only 0.5 to 1 billion people. Such is the climate and ecological emergency.

The warnings could not be more serious. We need all our cities and communities, let alone buildings, to be zero carbon without delay.

To write this report, industry experts, have come together under Clara's leadership to produce essential guidance for how to design and build zero carbon buildings. It is particularly inspiring to see so many young professionals contributing to the report. It has clear recommendations on design and management processes and technologies to ensure buildings can contribute to a zero carbon future – both operational carbon released from use of the buildings as well as the carbon embodied in construction. A huge amount has been learned over the past twenty and more years on how to design, build and operate zero carbon buildings. So much of that learning in distilled in this report. The guidance is a snapshot of what good looks like today. It will need to evolve over time as we learn more, as new technology emerges and contexts change. Perhaps we should aim to update it at least every five years.

As well as guidance, this report provides exceptionally good material to inform policy. What makes good guidance does not necessarily make good policy. Over the next few months we should translate the thinking behind this guidance into policy recommendations to get the new decade off to a good start. We will do well to learn from what worked and what didn't work in the ill-fated Zero Carbon Homes policy introduced and abandoned in the last decade. To be effective in policy terms, zero carbon buildings must be seen and deployed in the context of zero carbon energy policy and zero carbon transport policy. Without these, it will be hard to deliver at scale on the aspirations contained in this report. We need to ensure that the right system is being tackled to deliver the carbon savings effectively and cost-effectively and not the whole burden falling on new buildings, particularly new homes.

The time has come to get sustainability done. This report provides an important roadmap for buildings. Please read it. Absorb it contents. Learn from it. Build your understanding and apply it sensibly, responding to the unique needs of your building and the context which contains it.

Pooran Desai OBE Hon FRIBA

CEO Oneplanet.com

Co-founder, Bioregional

Contents

Executive summary

The climate emergency - a call to action

We are in a climate emergency, and urgently need to reduce carbon emissions. Here in the UK, 49% of annual carbon emissions are attributable to buildings. Over the next 40 years, the world is expected to build 230 billion square metres of new construction[1] – adding the equivalent of Paris to the planet every single week – so we must act now to meet the challenge of building net zero developments.

LETI, along with others such as the World Green Building Council and Architecture 2030, believe that in order to meet our climate change targets all new buildings must operate at net zero carbon by 2030 and all buildings must operate at net zero carbon by 2050. This document provides practical solutions to set out a definitive journey, beyond climate emergency declarations, into a net zero future. To this end, the solution to meeting our climate change targets must be:

→ **Scalable:** Energy consumption targets are set so that there is enough renewable energy to power all buildings in the UK.
→ **Achievable:** A comprehensive modelling study has been undertaken, and in-use data from buildings have been analysed, so that the targets, while ambitious to achieve, are deemed achievable for most projects.
→ **Verifiable:** Targets are measured in-use.
→ **Whole Life:** Embodied carbon and operational carbon must both be considered.

For this document net zero carbon means whole life carbon. **Whole life carbon** is formed of two key components:

Operational Carbon: a new building with net zero operational carbon does not burn fossil fuels, is 100% powered by renewable energy, and achieves a level of energy performance in-use in line with our national climate change targets.

Embodied Carbon: Best Practice targets for embodied carbon are met, and the building is made from re-used materials and can be disassembled at its end of life in accordance with the circular economy principles.

The built environment industry, together with current regulations and practices, are seriously lagging behind the carbon trajectory required to protect life on planet earth. Everyone's future is at stake. As an industry we must be absolutely confident that all new buildings can operate at net zero carbon from 2030.

Embodied Carbon : The carbon emissions emitted producing a building's materials, their transport and installation on site as well as their disposal at end of life.

- Products
- Transport
- Construction
- Maintenance and replacement
- End of life disposal

1 - UN Global Status Report 2017

In order to achieve this, LETI believes that by 2025, 100 percent of new buildings must be designed to deliver net zero carbon, and the whole construction industry will need to be equipped with the knowledge and skills necessary.

To set us on this trajectory, LETI believes that in 2020, 10 percent of all new buildings need to be designed to deliver net zero carbon (see Figure i). This allows time for lesson learning, knowledge transfer, and market uptake – but only if we all act now.

This document represent LETI's understanding of how we need to be designing to meet our climate change targets in 2020. This guide will evolve over time reflecting change in carbon budgets, technologies and capability of industry. LETI is collaborative by nature and is very interested in your feedback, go to the LETI website to find a general feedback form on the design guide, with specific questions on embodied carbon and demand response.

For more information on LETI, please see:
www.LETI.london

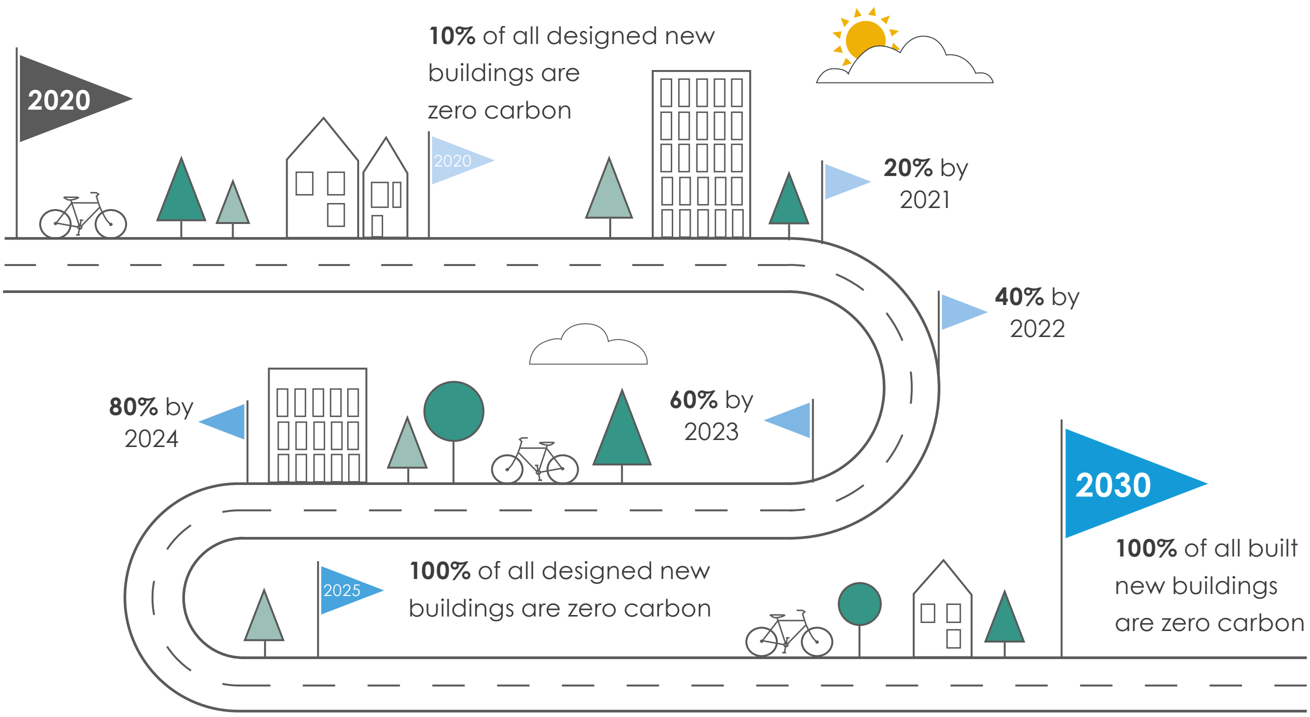

Figure i - LETI – Getting to Zero

We all have a role to play

Every stakeholder working in the built environment has a part to play, and all must work together, with the same collective ambition, for net zero carbon to be delivered at scale.

The most aspirational designer can be limited by a client with a narrow strategic vision, and the most aspirational client can be limited by design teams unskilled in delivering net zero carbon. Regulation and policy must be implemented quickly so that the minimum standards are set to deliver net zero carbon.

This document is intended to help the industry understand and deliver new buildings that are net zero carbon. It is specifically aimed towards developers/ landowners, designers, policy makers, and the supply chain. It aims to help to define 'good' and to set clear and achievable targets.

This document seeks to:

→ **Aid clients and developers in setting briefs and strategies** both at organisational and project levels, which are required to develop net zero carbon buildings.

→ **Support design teams** with easy-to-follow best practice guidance on delivering net zero.

→ **Outline to planners, policymakers, local and central government what to expect** for the delivery and hence the policy framework needed for net zero carbon new buildings.

Structure of this report

The guidance in the document outlines how we should be designing buildings now, from 2020. Buildings that currently meet these requirements in-use will be seen as leaders. By 2030 these requirements must become standard practice.

The introduction outlines in further detail the magnitude of the challenges that this industry faces, as well as the approach taken by LETI to establish this guidance. Actions that must be taken at each RIBA design stage have been summarised in Appendix 0.

Our methodology includes setting the requirements of four key building archetypes (small scale residential, medium/large scale residential, commercial offices, and schools).

Five chapters follow the introduction, delving into details on delivery and implementable solutions (Figure ii). Each chapter forms a key component of the journey towards a zero carbon future.

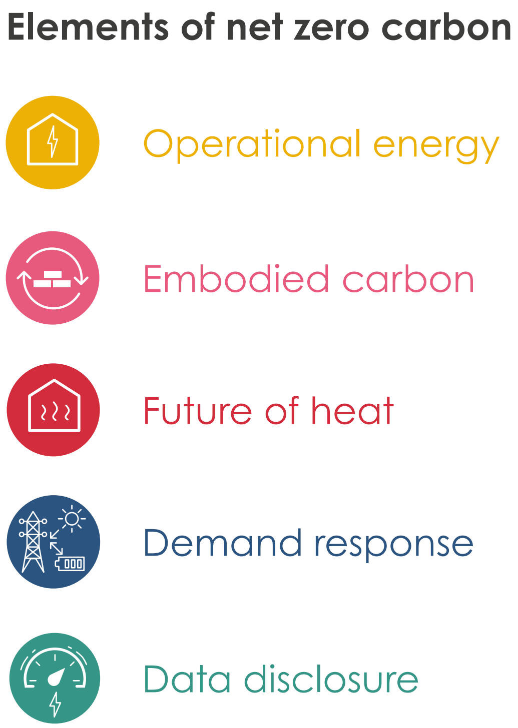

Figure ii - Elements of net zero carbon

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Introduction

0.0 Introduction

We are in a climate crisis and the construction industry is responsible for 49% of carbon emissions in the UK (see Figure 0.1). Therefore we must take rapid action to decarbonise the building industry.

In order to limit climate change, the UK government is committed to achieving net zero emissions by 2050. LETI along with other organisations believe that this is not sufficient. Global warming is predicted to be limited to 1.5°C only if drastic changes are made, Figure 0.2 shows the magnitude of the change needed to reach net zero carbon.

0.1 Scope of this document

LETI has taken the strategic decision to focus this report on new buildings. We acknowledge that a significant portion of the built environment in 2050 (c. 80 percent) already exists and will need an equal amount of attention by the industry, in order to fulfil our responsibility towards the climate emergency.

The focus on new buildings has been prioritised as it is crucial that all new buildings are developed to a standard that meets our climate change targets. If not, the new buildings will just compound the problem, and ultimately add to the number existing buildings requiring deep retrofit to meet our climate change

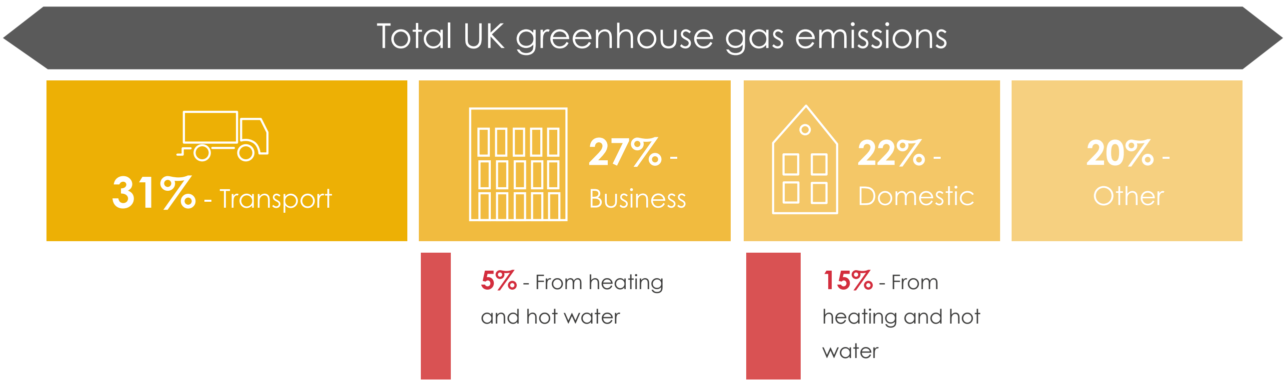


Figure 0.1 - The UK's carbon footprint

Source: Information in figure 0-01 has been developed from a variety of sources. 1. National Statistics, Annex: 1990-2017 UK Greenhouse Gas Emissions, Final Figures by End User, Issued 28/03/19. 2. Committee on Climate Change, UK housing: Fit for the future? February 2019. 3. Committee on Climate Change, Reducing UK Emissions - 2019 Progress Report to Parliament. 4. Environmental Change Institute, 40% House, 2005 targets. New buildings also offer the opportunity to test techniques and systems that can then be applied to the existing building stock.

It is important to note that this document focuses on requirements and solutions related to carbon emissions. Other aspects such as overheating, air quality, and wellbeing are also seen as important and must be taken into consideration when designing a building - but are beyond the scope of this document.

Due to the rapidly evolving nature of emerging knowledge in this field, this document should be read in conjunction with the latest guidance and technical toolkits available, including (but not limited to) those from the UKGBC, RICS, CIBSE, and the RIBA. We hope this document offers easy-to-follow guidance for designers and urban planners to better understand how to reduce whole life carbon in the design and construction of buildings.

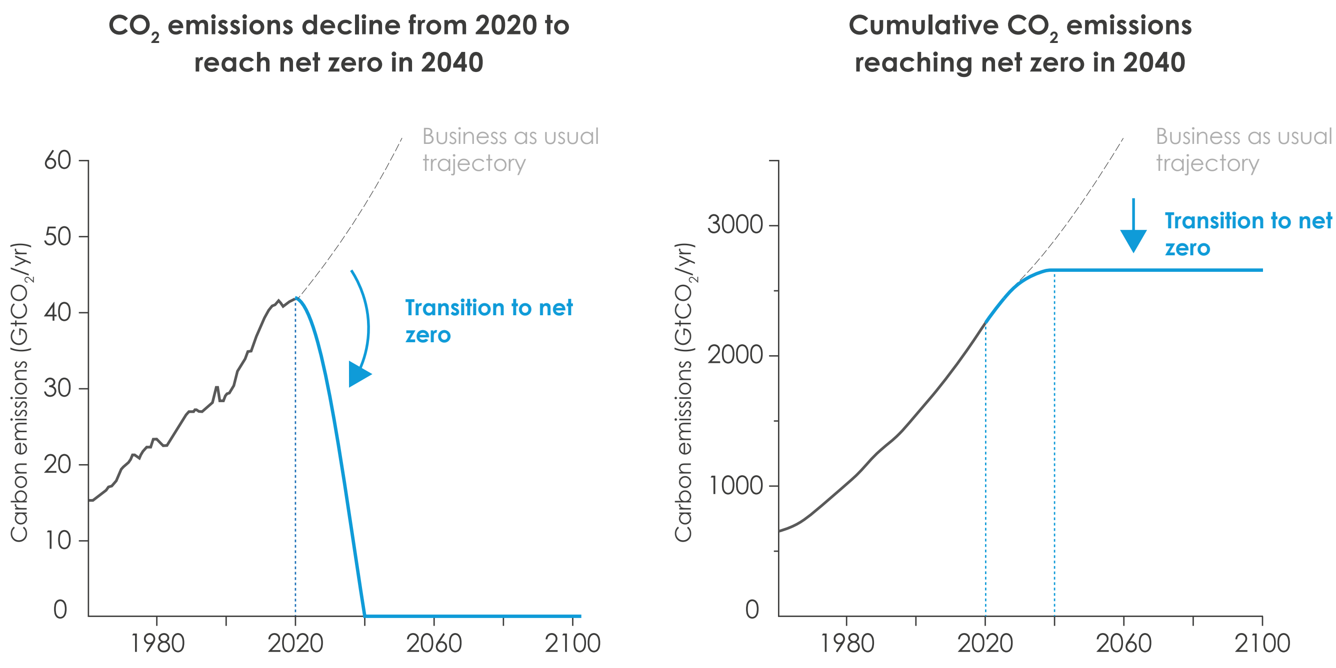


Figure 0.2 - Magnitude of global carbon emission reductions required to limiting warming to 1.5°C. Intergovernmental Panel on Climate Change.

0.2 The elements of whole life carbon

Net zero carbon needs to be considered in the context of whole life carbon. Whole life carbon includes operational and embodied carbon, and these need to be understood, and considered, very differently.

Operational - zero carbon balance

A new building with net zero operational carbon does not burn fossil fuels, is 100% powered by renewable energy, and achieves a level of energy performance in-use in line with our national climate change targets. This means that an operational carbon balance is met, see Figure 0.3. LETI has carried out extensive consultation on the key requirements for net zero operational carbon for new buildings. No carbon offsets can be used to achieve this balance.

SIGNPOST *Appendix 0 - Net zero operational carbon*

For some building types, such as small scale residential, 100 % of the energy consumption can be met on-site with roof mounted PV panels. Taller buildings have a smaller proportion of roof area to floor area, therefore investment in 'additional' renewable energy off-site will be required. Such investment into additional renewable energy capacity is not considered an offset.

As well as achieving the 'zero carbon balance' at a building level, it is important that this balance is also achieved at a national level (see Figure 0.4). To meet the UK's climate change targets all buildings must achieve net zero operational carbon. Because the amount of renewables that the UK can produce is limited, to achieve operational net zero carbon at scale in the UK, developments must not exceed an 'energy budget'. This is set as an Energy Use Intensity (EUI) target (see section 0.6 Key definitions).

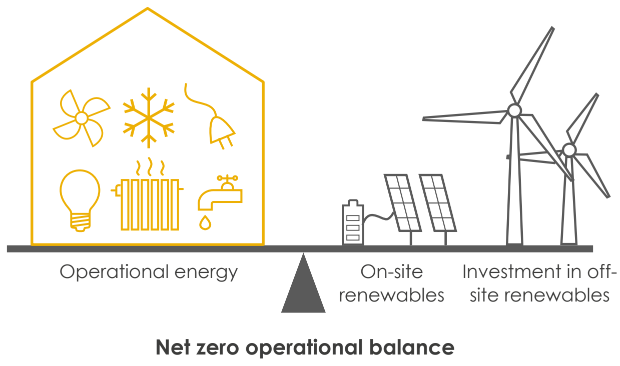


Figure 0.3 - Net zero operational balance - at the building scale

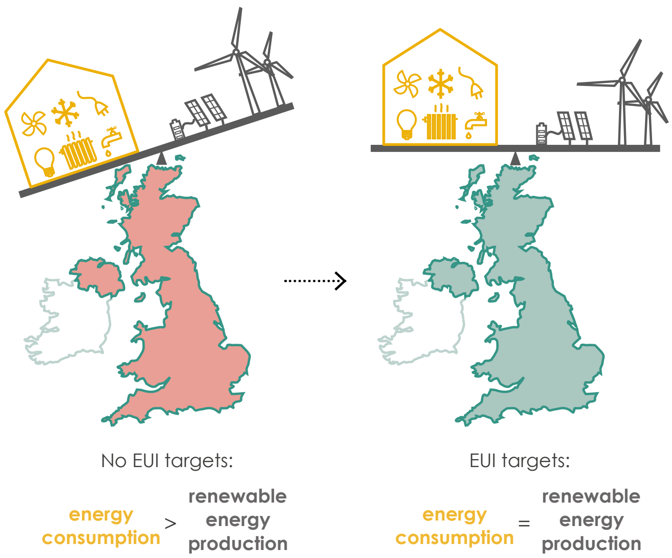


Figure 0.4 - Net zero operational balance - at UK scale

Embodied carbon

Operational carbon is based on the flow of energy and needs to be generated through renewables. Constructing buildings uses energy as well as resources, and once a building has come to the end of its life, these resources are still potentially available for use. Thus in addition to reducing embodied carbon we must consider the resources as a 'store' rather than a 'flow' and buildings should be thought of as 'material resource banks'.

The embodied carbon emissions need to be considered within national and regional carbon budgeting. This means that the carbon emissions themselves need to be reduced which is why LETI has set embodied carbon targets for the upfront embodied carbon emissions (Building Life Cycle Stage A1-A5). In addition, the material resources used need to be kept in the circular economy. This means that the building re-uses materials and products from demolished buildings, and is designed for disassembly, so that materials and products within the building can be re-used in future buildings.

LETI defines whole life carbon best practice as a building that meets the operational zero carbon balance, and that meets best practice targets for embodied carbon, including upfront embodied carbon targets, proportion of materials that are from re-used sources and proportion of materials that can be re-used in future buildings.

Whole life net zero carbon

One school of thought is that offsetting can be used to achieve net zero embodied carbon. However, offsets are a controversial subject, with significant issues related to transparency and effectiveness. This guidance document does not expand on offsets as this bears no relation to the performance of a building. LETI have taken a view that circularity is more relevant than offsets for the design team and for policy makers. However, as offsets can be seen as means to reduce the residual emissions of embodied carbon Appendix 10 of the Embodied Carbon Primer gives a dispassionate review of offsetting, looking at the advantages, disadvantages and technical and societal challenges to its effective implementation.

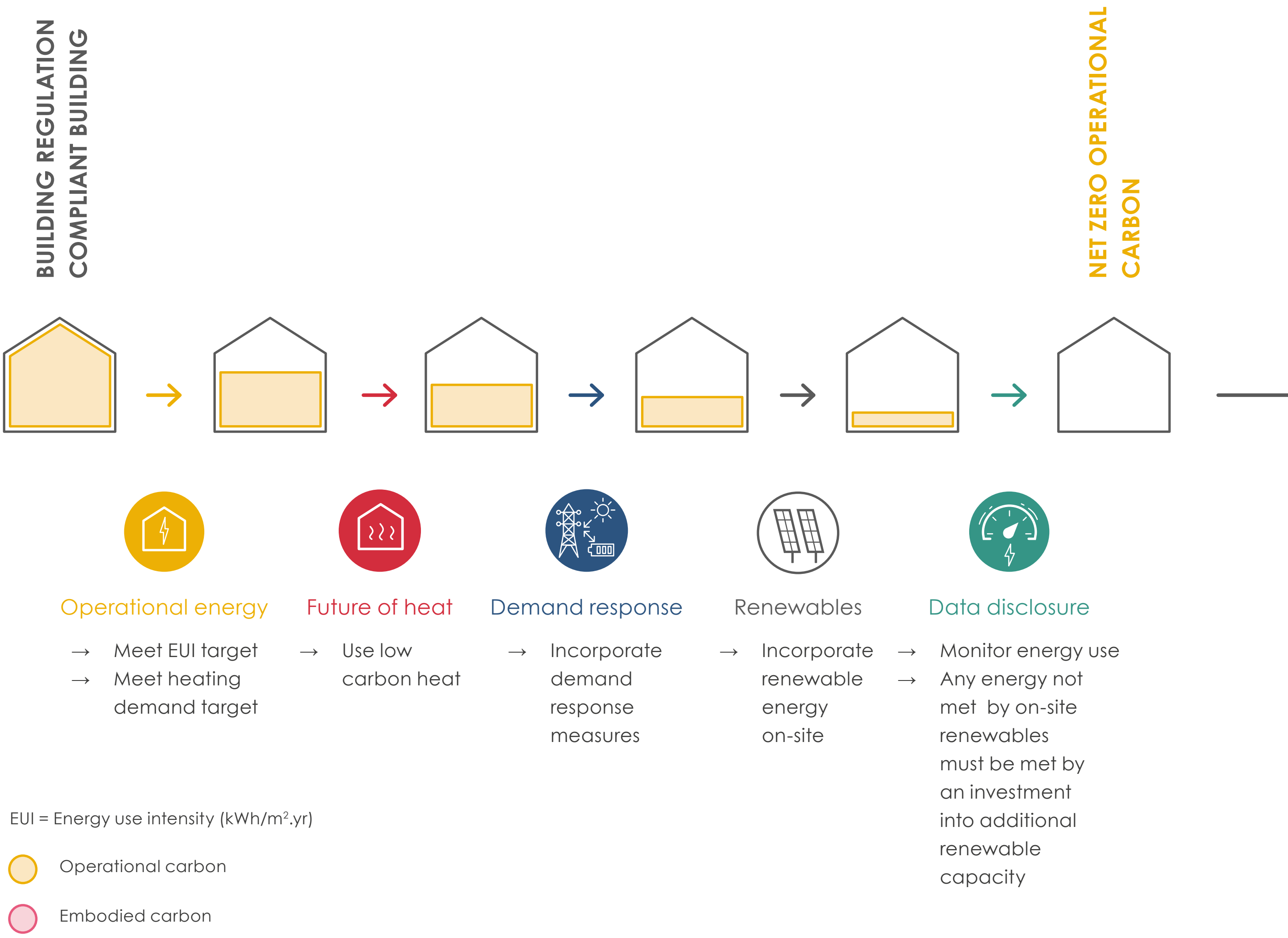
A building that is whole life net zero carbon meets the operational zero carbon balance and is 100% circular, this means that 100% of its materials and products are made up of re-used materials and the building is designed for disassembly such that 100% of its materials and products can be re-used in future buildings. When construction, transport and disassembly is carried out with renewable energy there will be zero carbon emissions associated with the embodied carbon.

SIGNPOST *Embodied Carbon Primer - Appendix 10 - Carbon offsets*

Whole life carbon explained

Whole life carbon encompasses all carbon emissions that arise as a result of the energy used in the construction, operation, maintenance and demolition phases of a building.

Figure 0.5 shows the operational carbon reduction stages on the left, and the embodied carbon reduction stages on the right.



Whole life carbon = Operational carbon + Embodied carbon

A new building that meets net zero operational carbon does not burn fossil fuels, is 100% powered by renewable energy, and achieves a level of energy performance in-use in line with our national climate change targets. See Appendix 0.

Best Practice targets for embodied carbon are met, the building is made from re-used materials and can be disassembled at end of its life - in accordance with the circular economy principles.

SIGNPOST
Chapters 1,3,4 and 5 cover operational carbon

SIGNPOST
Chapter 2 and the Embodied Carbon Primer cover embodied carbon

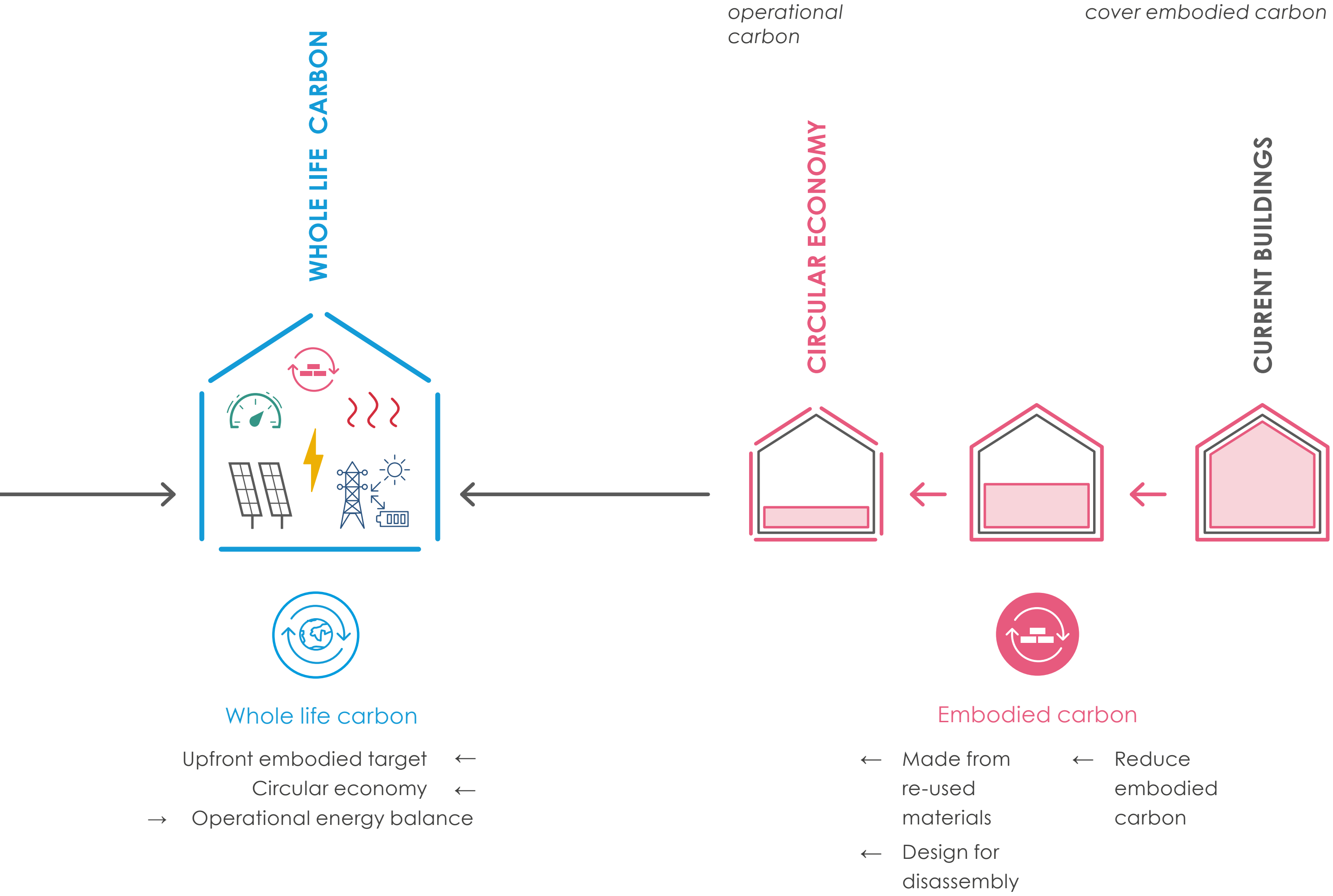


Figure 0.5 - Whole life carbon

0.3 Chapter guide

Operational energy

Operational energy is the energy consumed by a building associated with heating, hot water, cooling, ventilation, and lighting systems, as well as equipment such as fridges, washing machines, TVs, computers, lifts, and cooking. Reducing operational energy is key to achieving scalable zero carbon. The archetype summary pages outline performance requirements and Chapter 1 provides guidance on the key levers that drive operational performance.

SIGNPOST *Chapter 1 - Operational energy*

Embodied carbon

The term embodied carbon refers to the 'upfront' emissions associated with building construction, including the extraction and processing of materials and the energy and water consumption in the production, assembly, and construction of the building. It also includes the 'in-use' stage (the maintenance, replacement, and emissions associated with refrigerant leakage) and the 'end of life' stage (demolition, disassembly, and disposal of any parts of product or building) and any transportation relating to the above. Embodied carbon is a topic that is becoming more relevant and important as we reduce operational carbon.

Currently there is a lack of knowledge in the built environment industry surrounding embodied carbon reduction strategies and calculations, and the verification of the installed materials. Therefore LETI has produced supplementary guidance in the form of the LETI Embodied Carbon Primer. The key messages from the primer are summarised in Chapter 2 of this report.

SIGNPOST *Chapter 2 - Embodied carbon*

SIGNPOST *Embodied Carbon Primer*

Future of heat

The decarbonisation of heating and hot water will have a huge impact on carbon emission reductions and is a crucial step in the net zero pathway. Chapter 3 showcases the LETI Heat Decision Tree, a tool that can be used to help identify the most appropriate low carbon heating system.

SIGNPOST *Chapter 3 - Future of heat*

Demand response

Integrating demand response and energy storage into buildings allows buildings to be flexible with their demand on the grid for power. This is fundamental to allow the grid to harness renewable energy sources that allows it to decarbonise to a level that is needed to meet our climate change targets. Chapter 4 outlines key actions that can be taken to improve a building's power flexibility.

SIGNPOST *Chapter 4 - Demand response*

Data disclosure

Unless we can gain a good understanding of how our buildings are performing in-use through post occupancy evaluation, we cannot achieve net zero carbon. Currently the way that buildings are assessed in regulations is according to a Building Regulations energy model (Part L) rather than in-use consumption. There is also a huge 'performance gap' between how we estimate the energy consumption of new buildings and how they perform in-use. Chapter 5 outlines the steps we need to take to start understanding how our buildings are performing in-use by better measuring and monitoring energy consumption.

SIGNPOST *Chapter 5 - Data disclosure*

0.4 Capacity building

As well as design teams focusing on the 5 key themes, regulations and policy will also be needed to incentivise and mandate net zero carbon.

Significant leaps will need to be made upskilling and capacity building, to ensure that the built environment industry has the skills to deliver net zero buildings. This document has been developed as a first step towards this.

Upskilling will be required in the following areas:

Energy Modelling: To ensure the correct motivation drives energy modelling, there must be a legal responsibility to ensure it is directly reconciled against in-use measured energy use. So rather than just compliance modelling, the UK needs to upskill in predictive modelling. This means that design decisions such as fabric performance and system selection can be based on predictions of energy consumption reduction. Demand response measures that increase the 'energy flexibility' of the development can also be assessed.

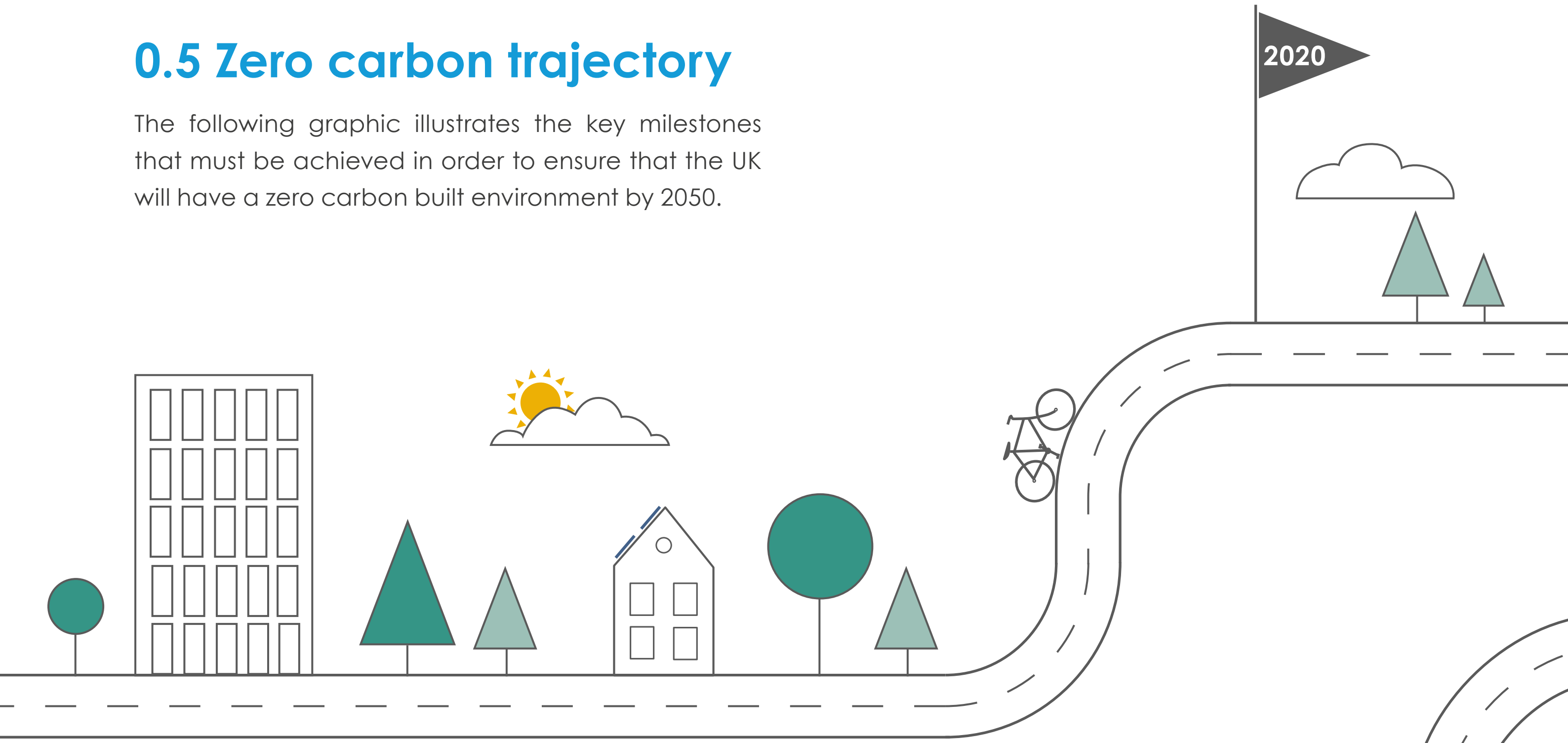
Designing: The whole design team needs to understand their individual contributions towards reductions of operational energy and embodied carbon in a cost-effective way. A 'golden thread' of responsibility from design through construction and into operation will be needed to ensure decisions are implemented and their operation verified.

Constructing: Contractors need to learn how to construct buildings that achieve high levels of airtightness and insulation and effectively reduce/eliminate the effects of thermal bridging. The full implications of specification substitution must be clearly defined.

Operating and facilities management: The role of the facilities manager in reducing carbon emissions needs to be properly recognised. Performance outcomes need to be based on energy consumption. On a smaller scale, users need to be made aware of how to operate their building in a low carbon way.

0.5 Zero carbon trajectory

The following graphic illustrates the key milestones that must be achieved in order to ensure that the UK will have a zero carbon built environment by 2050.

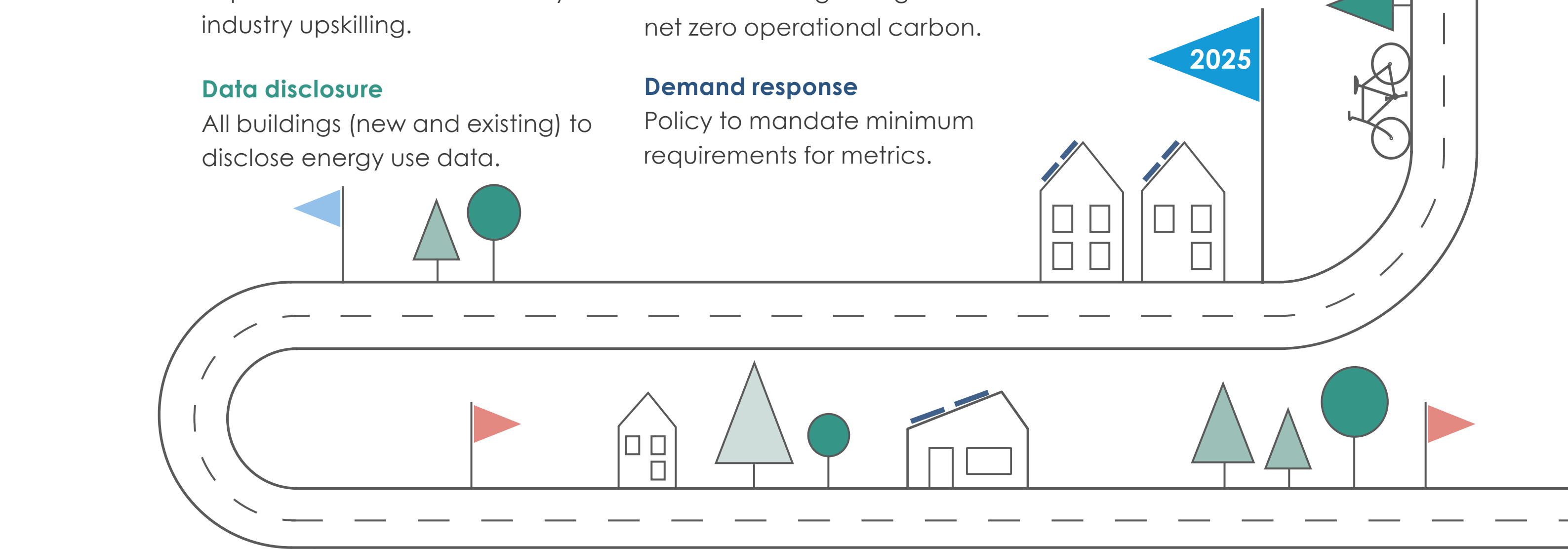


2025-2030
Improved cost-effectiveness by industry upskilling.

Data disclosure
All buildings (new and existing) to disclose energy use data.

Operational energy
All new buildings designed to be net zero operational carbon.

Demand response
Policy to mandate minimum requirements for metrics.



2030

Operational energy
All new buildings to operate at net zero operational carbon.

Embodied carbon
All new buildings achieve a 65% reduction in embodied carbon emissions.

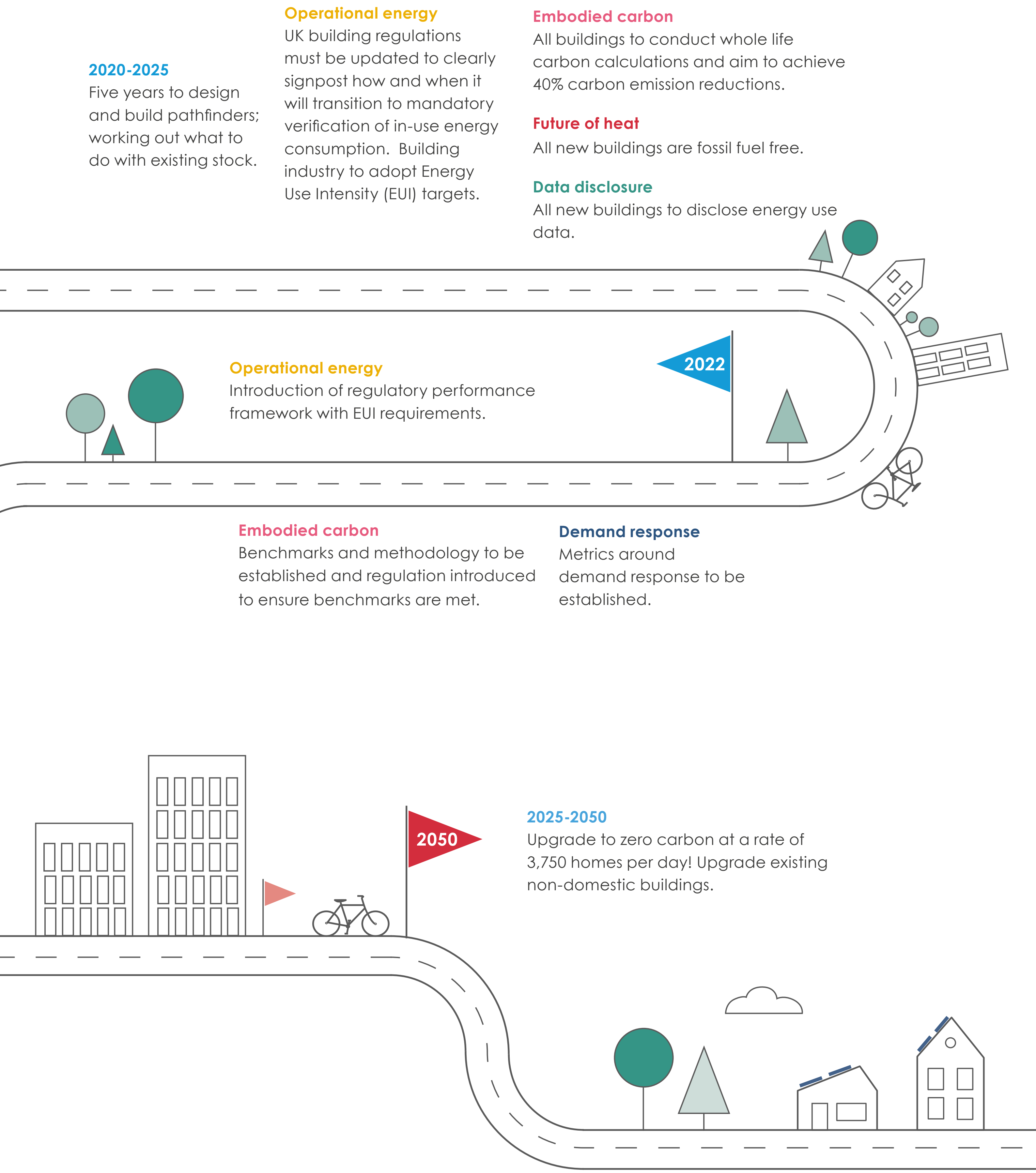


Figure 0.6 - Zero carbon trajectory

0.6 Key definitions

Key definitions and abbreviations used in this guide:

What is an EUI?
The Energy Use Intensity (EUI) is an annual measure of the total energy consumed in a building.

LETI believes that setting an EUI requirement for new buildings is fundamental to meeting our climate change targets. It is a good indicator for building performance as the metric is solely dependent on how the building performs in-use; rather than carbon emissions, which also reflect the carbon intensity of the grid.

EUI is a metric that can be estimated at the design stage and very easily monitored in-use as energy bills are based on kWh of energy used by the building. This metric can be used to compare buildings of a similar type, to understand how well the building performs in-use. It includes all of the energy consumed in the building, such as regulated energy (heating, hot water, cooling, ventilation, and lighting) and unregulated energy (plug loads and equipment e.g. kitchen white goods, ICT/AV equipment). It does not include charging of electric vehicles.

EUI can be expressed in GIA (Gross Internal Area) or NLA (Net Lettable Area). In this document the EUIs are expressed in GIA unless specified.

EUI should replace carbon emission reductions as the primary metric used in policy, regulations, and design decisions.

Regulated energy: Energy consumed by a building, associated with fixed installations for heating, hot water, cooling, ventilation, and lighting systems.

Unregulated energy: Energy consumed by a building that is outside of the scope of Building Regulations, e.g. energy associated with equipment such as fridges, washing machines, TVs, computers, lifts, and cooking.

Operational carbon (kgCO_2e): The carbon dioxide and equivalent global warming potential (GWP) of other gases associated with the in-use operation of the building. This usually includes carbon emissions associated with heating, hot water, cooling, ventilation, and lighting systems, as well as those associated with cooking, equipment, and lifts (i.e. both regulated and unregulated energy uses).

Embodied energy: The total primary energy consumed (e.g. in MJ) from direct and indirect processes associated with the production of a product or system. This is considered within the boundaries of cradle-to-gate.

Upfront embodied carbon: The carbon emissions associated with the extraction and processing of materials, the energy and water consumption used by the factory in producing products, transporting materials to site, and constructing the building.

Embodied carbon (EC): The carbon emissions associated with the extraction and processing of materials and the energy and water consumption used by the factory in producing products and constructing the building. It also includes the 'in-use' stage (maintenance, replacement, and emissions associated with refrigerant leakage) and 'end of life' stage (demolition, disassembly, and disposal of any parts of product or building) and any transportation relating to the above.

Whole life carbon (WLC): This includes embodied carbon, as defined above, and operational carbon. The purpose of using WLC is to move towards a building or a product that generates the lowest carbon emissions over its whole life (sometimes referred as 'cradle-to-grave').

Primary energy: Primary energy is energy that has not undergone any conversion or transformation. As a common example, each kWh of grid electricity used in a UK building requires 1.5 kWh of primary energy; this accounts for the energy required for power generation (including fuel extraction and transport to thermal or nuclear power stations), transmission and distribution.

Circular economy: A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the linear economy and its 'end of life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals and aims for the elimination of waste through the design of materials, products, systems that can be repaired and reused.

SIGNPOST *Appendix 6 - Definitions*

0.7 Building archetypes

This guide focuses on four building archetypes that make up the majority of new buildings in the UK. Taken together they represent 75% of the new buildings likely to be built between now and 2050.

Archetypes detailed in this report:

→ **Small scale residential:** terraced or semi-detached houses
→ **Medium and large scale residential:** four floors and above
→ **Commercial offices**
→ **Schools:** Primary or secondary

The following pages show the key performance indicators to meet whole life carbon for the four building typologies.

0.8 Actions by RIBA Stage

Appendix 0.2 shows the actions required to meet net zero carbon for each RIBA Stages. This helps understand which actions need to be taken at each stage to ensure whole life carbon is achieved.

SIGNPOST *Appendix 0 - Actions by RIBA Stage*

Small scale housing

Operational energy

Implement the following indicative design measures:

Fabric U-values (W/m².K)

Walls	0.13 - 0.15
Floor	0.08 - 0.10
Roof	0.10 - 0.12
Exposed ceilings/floors	0.13 - 0.18
Windows	0.80 (triple glazing)
Doors	1.00

Efficiency measures

Air tightness	<1 (m^3/h. m^2@50Pa)
Thermal bridging	0.04 (y-value)
G-value of glass	0.6 - 0.5
MVHR	90% (efficiency) ≤2m (duct length from unit to external wall)

Window areas guide (% of wall area)

North	10-15%
East	10-15%
South	20-25%
West	10-15%

Balance daylight and overheating

Include external shading

Include openable windows and cross ventilation

Reduce energy consumption to:

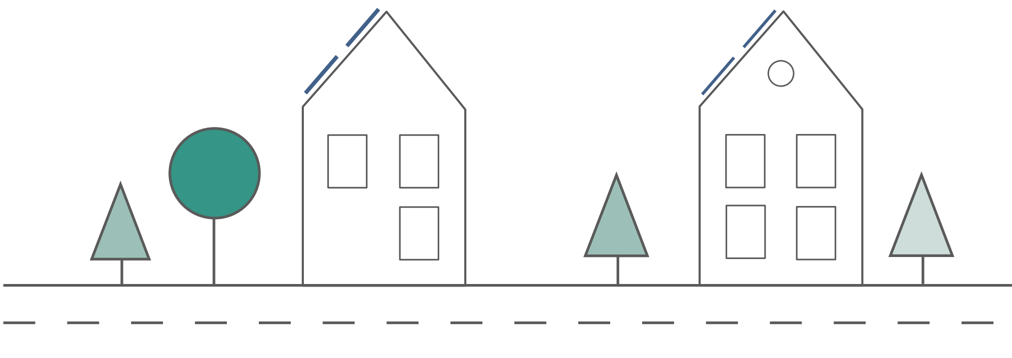
35 kWh/m².yr

Energy Use Intensity (EUI) in GIA, excluding renewable energy contribution

Reduce space heating demand to: 15 kWh/m².yr

Maximise renewables so that 100% of annual energy requirement is generated on-site

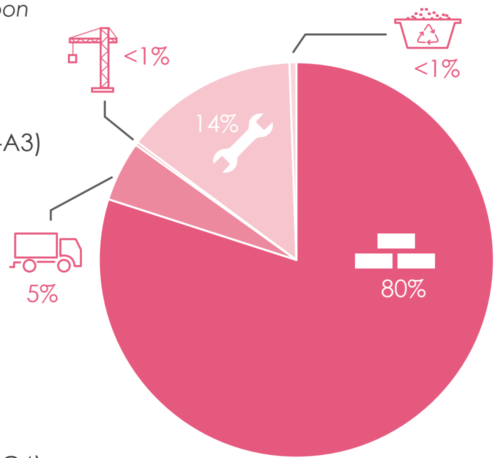
Form factor of 1.7 - 2.5



Embodied carbon

Focus on reducing embodied carbon for the largest uses:

- Products/materials (A1-A3)
- Transport (A4)
- Construction (A5)
- Maintenance and replacements (B1-B5)
- End of life disposal (C1-C4)



Average split of embodied carbon per building element:

30% - Superstructure

27% - Substructure

20% - Internal finishes

17% - Façade

5% - MEP

Reduce embodied carbon by 40% or to:

<500 $kgCO_2/m^2$

Area in GIA

Heating and hot water

Implement the following measures:

Fuel
Ensure heating and hot water generation is fossil fuel free

Heating
Maximum 10 W/m^2 peak heat loss (including ventilation)

Hot water
Maximum dead leg of 1 litre for hot water pipework

'Green' Euro Water Label should be used for hot water outlets (e.g.: certified 6 L/min shower head – not using flow restrictors).

Demand response

Implement the following measures to smooth energy demand and consumption:

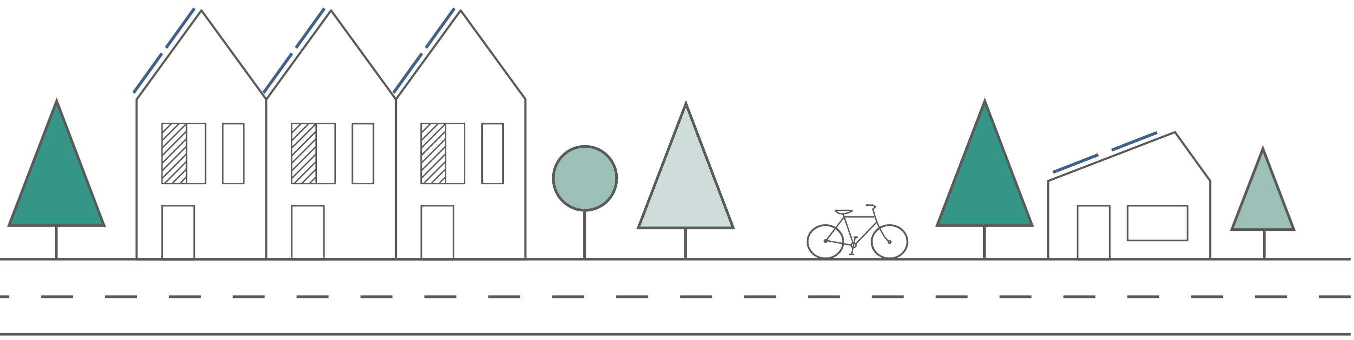
Peak reduction
Reduce heating and hot water peak energy demand

Active demand response measures
Install heating set point control and thermal storage

Electricity generation and storage
Consider battery storage

Electric vehicle (EV) charging
Electric vehicle turn down

Behaviour change
Incentives to reduce power consumption and peak grid constraints.



Data disclosure

Meter and disclose energy consumption as follows:

Metering

1. Submeter renewables for energy generation
2. Submeter electric vehicle charging
3. Submeter heating fuel (e.g. heat pump consumption)
4. Continuously monitor with a smart meter
5. Consider monitoring internal temperatures
6. For multiple properties include a data logger alongside the smart meter to make data sharing possible.

Disclosure

1. Collect annual building energy consumption and generation
2. Aggregate average operational reporting e.g. by post code for anonymity or upstream meters
3. Collect water consumption meter readings
4. Upload five years of data to GLA and/or CarbonBuzz online platform
5. Consider uploading to Low Energy Building Database.

Medium and large scale housing

Operational energy

Implement the following indicative design measures:

Fabric U-values (W/m².K)

Walls	0.13 - 0.15
Floor	0.08 - 0.10
Roof	0.10 - 0.12
Exposed ceilings/floors	0.13 - 0.18
Windows	1.0 (triple glazing)
Doors	1.00

Efficiency measures

Air tightness	<1 (m³/h.m²@50Pa)
Thermal bridging	0.04 (y-value)
G-value of glass	0.6 - 0.5
MVHR	90% (efficiency) ≤2m (duct length from unit to external wall)

Maximise renewables so that 70% of the roof is covered

Form factor of <0.8 - 1.5

Window areas guide (% of wall area)

North	10-20%
East	10-15%
South	20-25%
West	10-15%

Balance daylight and overheating

Include external shading

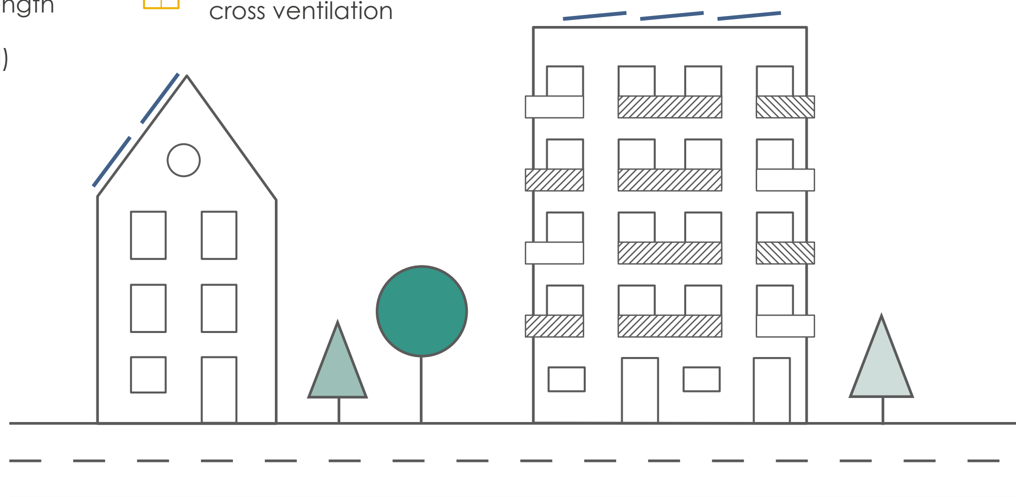
Include openable windows and cross ventilation

Reduce energy consumption to:

35 kWh/m².yr

Energy Use Intensity (EUI) in GIA, excluding renewable energy contribution

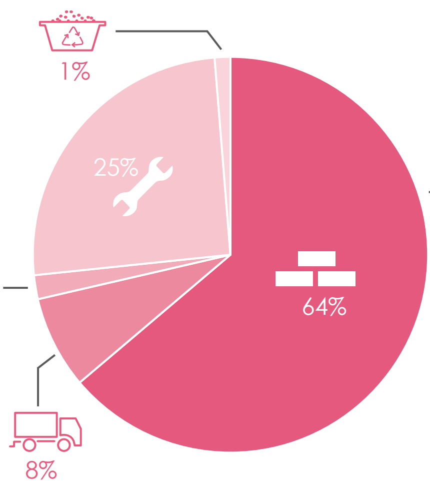
Reduce space heating demand to: **15** kWh/m².yr



Embodied carbon

Focus on reducing embodied carbon for the largest uses:

- Products/materials (A1-A3)
- Transport (A4)
- Construction (A5)
- Maintenance and replacements (B1-B5)
- End of life disposal (C1-C4)



Average split of embodied carbon per building element:

46% - Superstructure

21% - Substructure

16% - Internal finishes

13% - Façade

4% - MEP

Reduce embodied carbon by 40% or to:

<500 $kgCO_2/m^2$

Area in GIA

Heating and hot water

Implement the following measures:

Fuel
Ensure heating and hot water generation is fossil fuel free

Heat
The average carbon content of heat supplied (gCO_2/kWh.yr) should be reported in-use

Heating
Maximum 10 W/m^2 peak heat loss (including ventilation)

Hot water
Maximum dead leg of 1 litre for hot water pipework

'Green' Euro Water Label should be used for hot water outlets (e.g.: certified 6 L/min shower head – not using flow restrictors).

Demand response

Implement the following measures to smooth energy demand and consumption:

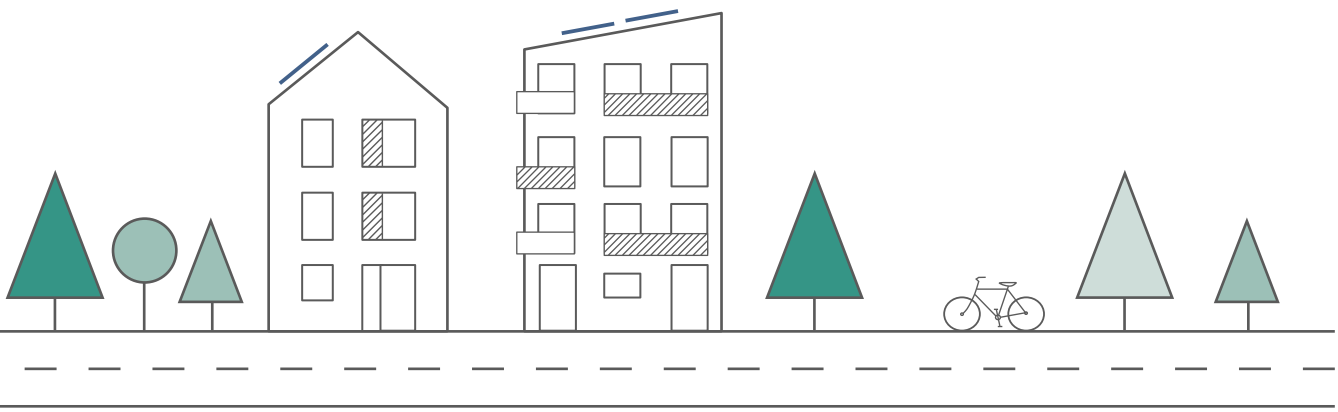
Peak reduction
Reduce heating and hot water peak energy demand

Active demand response measures
Install heating set point control and thermal storage

Electricity generation and storage
Consider battery storage

Electric vehicle (EV) charging
Electric vehicle turn down

Behaviour change
Incentives to reduce power consumption and peak grid constraints.



Data disclosure

Meter and disclose energy consumption as follows:

Metering

1. Submeter renewables for energy generation
2. Submeter electric vehicle charging
3. Submeter heating fuel (e.g. heat pump consumption)
4. Continuously monitor with a smart meter
5. Consider monitoring internal temperatures
6. For multiple properties include a data logger alongside the smart meter to make data sharing possible.

123 Disclosure

1. Collect annual building energy consumption and generation
2. Aggregate average operational reporting e.g. by post code for anonymity or upstream meters from part or whole of apartment block
3. Collect water consumption meter readings
4. Upload five years of data to GLA and/or CarbonBuzz online platform
5. Consider uploading to Low Energy Building Database.

Commercial offices

Operational energy

Implement the following indicative design measures:

Fabric U-values (W/m².K)

Walls	0.12 - 0.15
Floor	0.10 - 0.12
Roof	0.10 - 0.12
Windows	1.0 (triple glazing) - 1.2 (double glazing)
Doors	1.2

Fabric efficiency measures

Air tightness	<1 (m³/h. m²@50Pa)
Thermal bridging	0.04 (y-value)
G-value of glass	0.4 - 0.3

Power efficiency measures

Lighting power density	4.5 (W/m² peak NIA)
Lighting out of hours	0.5 (W/m² peak NIA)
Tenant power density	8 (W/m² peak NIA)
ICT loads	0.5 (W/m² peak NIA)
Small power out of hours	2 (W/m² peak NIA)

System efficiency measures

MVHR	90% (efficiency)
Heat pump SCoP	≥ 2.8
Chiller SEER	≥ 5.5
Central AHU SFP	1.5 - 1.2 W/l.s
A/C set points	20-26°C

Window areas guide (% of wall area)

North	25-40%
East	25-40%
South	25-40%
West	25-40%

Balance daylight and overheating

Include external shading

Include openable windows and cross ventilation

Maximise renewables to generate the annual energy requirement for at least two floors of the development on-site

Form factor of 1 - 2

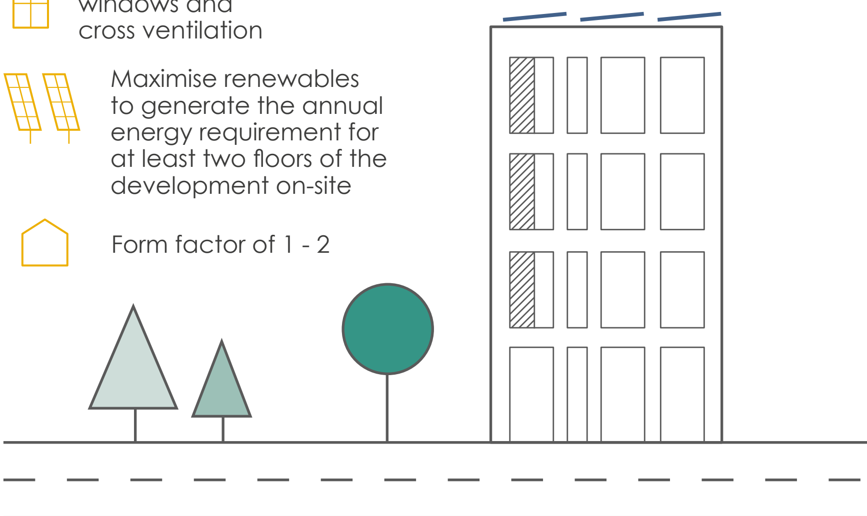
Reduce energy consumption to:

55 kWh/m².yr

Energy Use Intensity (EUI) in GIA, excluding renewable energy contribution

Reduce space heating demand to:

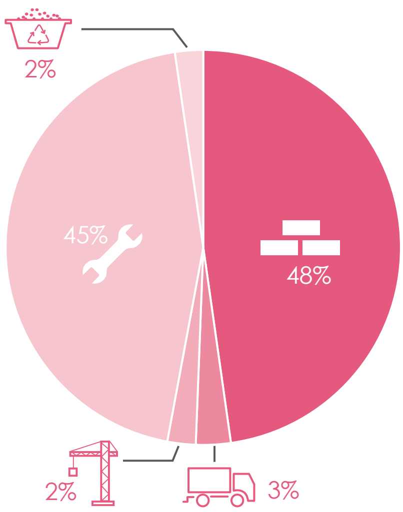
15 kWh/m².yr



Embodied carbon

Focus on reducing embodied carbon for the largest uses:

- Products/materials (A1-A3)
- Transport (A4)
- Construction (A5)
- Maintenance and replacements (B1-B5)
- End of life disposal (C1-C4)



Average split of embodied carbon per building element:

- **48%** - Superstructure
- **17%** - Substructure
- **16%** - Façade
- **15%** - MEP
- **4%** - Internal finishes

Reduce embodied carbon by 40% or to:

<600 $kgCO_2/m^2$

Area in GIA

Heating and hot water

Implement the following measures:

Fuel

Ensure heating and hot water generation is fossil fuel free

Heat

The average carbon content of heat supplied (gCO_2/kWh.yr) should be reported in-use

Heating

Maximum 10 W/m^2 peak heat loss (including ventilation)

Connect to community wide ambient loop heat-sharing network to allow excess heat from cooling to be made available to other buildings

Hot water

Maximum dead leg of 1 litre for hot water pipework

'Green' Euro Water Label should be used for hot water outlets (e.g.: certified 6 L/min shower head – not using flow restrictors).

Demand response

Implement the following measures to smooth energy demand and consumption:

Peak reduction

Reduce heating and hot water peak energy demand

Active demand response measures

Install heating and cooling set point control

Reduce lighting, ventilation and small power energy consumption

Electricity generation and storage

Consider battery storage

Electric vehicle (EV) charging

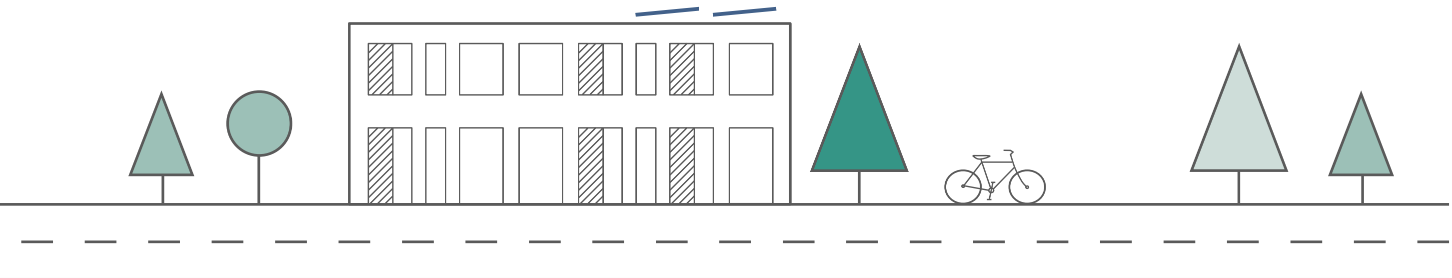
Electric vehicle turn down

Reverse charging EV technology

Behaviour change

Incentives to reduce power consumption and peak grid constraints

Encourage responsible occupancy.



Data disclosure

Meter and disclose energy consumption as follows:

Metering

(Metering strategy following BBP Better Metering Toolkit guidance)

1. Record meter data at half hourly intervals
2. Separate landlord and tenant energy use meters and clearly label meters with serial number and end use
3. Submeter renewable energy generation
4. Use a central repository for data that has a minimum of 18 months data storage
5. Provide thorough set of meter schematics and information on maintenance and use of meters
6. Ensure metering commissioning includes validation of manual compared to half hourly readings.

Disclosure

1. Carry out an annual Display Energy Certificate (DEC) and include as part of annual reporting
2. Report energy consumption by fuel type and respective benchmarks from the DEC technical table
3. For multi-let commercial offices produce annual landlord energy (base building) rating and tenant ratings as well as or instead of a whole building DEC
4. Upload five years of data to a publicly accessible database such as GLA and/or CarbonBuzz.

Schools

Operational energy

Implement the following indicative design measures:

Fabric U-values (W/m².K)

Walls	0.13 - 0.15
Floor	0.09 - 0.12
Roof	0.10 - 0.12
Windows	1.0 (triple glazing)
Doors	1.2

Fabric efficiency measures

Air tightness	<1 (m³/h. m²@50Pa)
Thermal bridging	0.04 (y-value)
G-value of glass	0.5 - 0.4

Power efficiency measures

Lighting power density	4.5 (W/m² peak NIA)
Lighting out of hours	0.5 (W/m² peak NIA)
Small power out of hours	2 (W/m² peak NIA)

System efficiency measures

MVHR	90% (efficiency)
Heat pump SCoP	≥ 2.8
Central AHU SFP	1.5 - 1.2 W/l.s

Maximise renewables so that 70% of the roof is covered

Window areas guide (% of wall area)

North	15-25%
East	15-25%
South	15-25%
West	15-25%

Balance daylight and overheating

Include external shading

Include openable windows and cross ventilation

Form factor of 1 - 3

Reduce energy consumption to:

65 kWh/m².yr

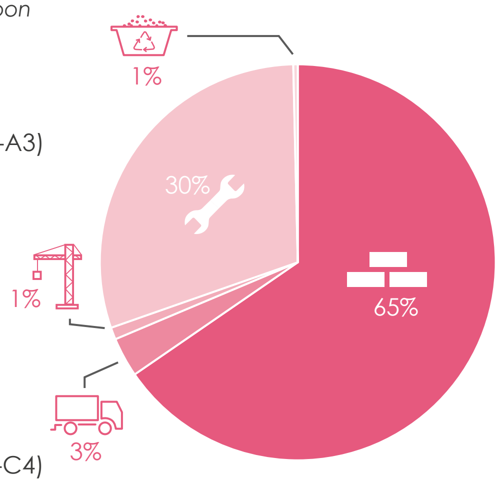
Energy Use Intensity (EUI) in GIA, excluding renewable energy contribution

Reduce space heating demand to: **15** kWh/m².yr

Embodied carbon

Focus on reducing embodied carbon for the largest uses:

- Products/materials (A1-A3)
- Transport (A4)
- Construction (A5)
- Maintenance and replacements (B1-B5)
- End of life disposal (C1-C4)



Average split of embodied carbon per building element:

- **30%** - Superstructure
- **21%** - Internal finishes
- **16%** - Substructure
- **16%** - Façade
- **13%** - MEP

Reduce embodied carbon by 40% or to:

<600 $kgCO_2/m^2$

Area in GIA

Heating and hot water

Implement the following measures:

Fuel
Ensure heating and hot water generation is fossil fuel free

Heat
The average carbon content of heat supplied (gCO_2/kWh.yr) should be reported in-use

Heating
Maximum 10 W/m^2 peak heat loss (including ventilation)

Hot water
Maximum dead leg of 1 litre for hot water pipework

'Green' Euro Water Label should be used for hot water outlets (e.g.: certified 6 L/min shower head – not using flow restrictors).

Demand response

Implement the following measures to smooth energy demand and consumption:

Peak reduction
Reduce heating and hot water peak energy demand

Active demand response measures
Install heating and cooling set point control

Reduce lighting, ventilation and small power energy consumption

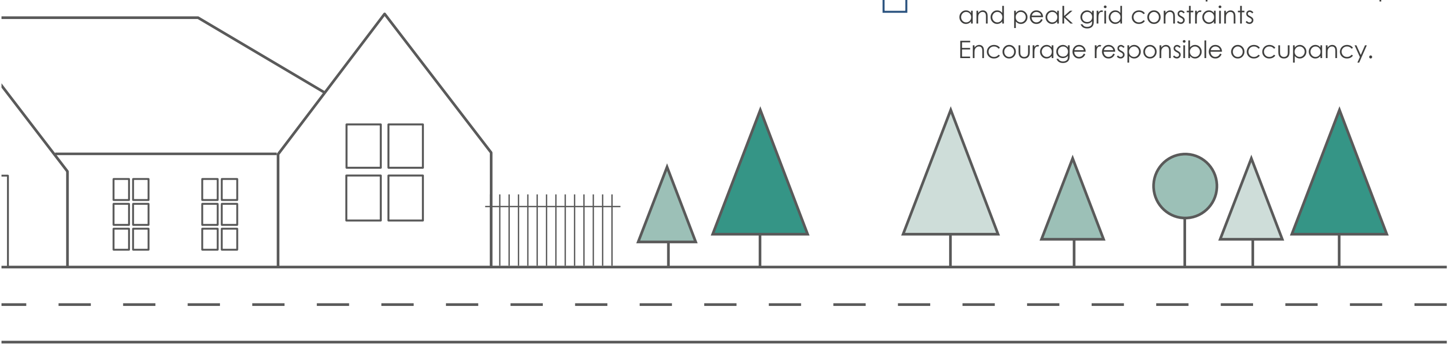
Electricity generation and storage
Consider battery storage

Electric vehicle (EV) charging
Electric vehicle turn down

Reverse charging EV technology

Behaviour change
Incentives to reduce power consumption and peak grid constraints

Encourage responsible occupancy.



Data disclosure

Meter and disclose energy consumption as follows:

Metering *(Metering strategy following BBP Better Metering Toolkit guidance)*

1. Record meter data at half hourly intervals
2. Clearly label meters with serial number and end use
3. Submeter renewable energy generation
4. Use a central repository for data that has a minimum of 18 months data storage
5. Provide thorough set of meter schematics and information on maintenance and use of meters
6. Ensure metering commissioning includes validation of manual compared to half hourly readings.

123 **Disclosure**

1. Carry out an annual Display Energy Certificate (DEC) and include as part of annual reporting
2. Report energy consumption by fuel type and respective benchmarks from the DEC technical table
3. Upload five years of data to a publicly accessible database such as GLA and/or CarbonBuzz. Include information about the building (do not anonymise).

1

Operational energy

Key performance indicators

1

Design for and achieve the **energy use intensity** (EUI) targets:

35 kWh/m².yr
Residential

55 kWh/m².yr
Offices

65 kWh/m².yr
Schools

2

Design for and achieve the **space heating demand** target:

15 kWh/m².yr
All building types

3

Maximise **renewable energy generation** on-site:

Small scale resi: Generate 100% of annual energy requirement on-site

Medium and large scale resi: Cover 70% of roof area

Offices: Generate the annual energy requirement for at least two floors of the development on-site

Schools: Cover 70% of the roof area

EUI targets above are based on GIA areas and exclude renewable energy contribution.

Summary

Client/developer (decision making)

- → Commit to a net zero carbon vision and disclose pathway towards achieving this goal.
- → Appoint key design team members to influence operational energy performance outcomes early in the design process.
- → Commit to energy benchmarking exercises and set established performance targets early in the design process - ideally prior to commencement of concept design (RIBA Stage 2).
- → Ensure that life cycle cost analysis and whole life carbon analysis are carried out for all projects, giving both appropriate weighting in value engineering decision making.
- → Commit to disclosure of regulated and unregulated building energy consumption at both design and operation stages.
- → Issue briefing documents that set out targets aligned with this guidance document.

Policymaker (strategy)

- → Request disclosure of key building performance metrics prior to planning approval. Evaluate performance against LETI archetypes and request clarification where targets are not being met.
- → Establish expertise within planning departments that are capable of assessing adherence to the key performance metrics.
- → Establish requirements (such as Supplementary Planning Guidance) that directly cite the recommendations set out in this document.
- → Apply equal or greater weighting to building operational performance than to aesthetic considerations in the overall context of the design, pre-application and determination process.

Designer (implementation)

- → Produce net zero operation pathways for projects in design, highlighting delivery strategies for through which net zero carbon can be delivered.
- → Design in accordance with the recommended key performance targets for each building archetype.
- → Ensure that design decisions reflect the energy hierarchy - seek to limit building energy demand through passive measures and efficient fabric design prior to considering systems' optimisation to satisfy demand.
- → Design to recommended heating and hot water coefficients of performance (COP). This includes heating, cooling, hot water and lighting demand kWh/m^2.yr.
- → System design to be carried out with consideration of both regulated and unregulated energy end uses.
- → Dedicate resources to staff learning and development to improve familiarity with key terminology and influence on building energy performance. This includes understanding key activities required within each RIBA work stage.

1.0 Introduction

Operational carbon refers to the carbon dioxide and other greenhouse gases which are emitted as a result of a building's energy use. This typically includes emissions associated with heating, hot water, cooling, ventilation and lighting systems, as well as energy used for cooking and by specialist equipment such as lifts.

This is distinctly different to 'embodied' carbon, which refers to the carbon emissions incurred from the manufacture, transport and erection of building materials used in the construction of a building (for detail see Chapter 2 - Embodied Carbon). Operational emissions can vary over the lifetime of the building and are governed by several factors, including building fabric efficiency, Heating, Ventilation and Air Conditioning (HVAC) system efficiency, fuel type, carbon factors and the way the building is used by the occupiers.

Historically, operational emissions have far outweighed the embodied emissions. However, as the efficiency of our buildings improves and carbon factors reduce, consideration of the embodied energy becomes increasingly important.

SIGNPOST *Chapter 2 - Embodied carbon*

3.1 Contribution to zero carbon (why do it?)

Operational carbon represents between 40% and 65% of a building's whole life carbon. It influences the ability to achieve a net zero built environment through a number of different interdependent factors, detailed below.

Operational carbon is arguably the most direct consistent environmental impact that a building has throughout its life cycle and is directly related to the ways in which we occupy and interact with buildings. It is a building's carbon legacy. In the context of the climate emergency, there is an urgent need to limit these ongoing impacts.

A net zero carbon building is first and foremost an energy efficient building.
LETI consider a building's low energy consumption to be the defining characteristic of an operational zero carbon building. Energy consumption is measured using Energy Use Intensity (EUI) with kWh/m^2.yr as a unit. Design approaches should begin with efforts to reduce building energy demand prior to the introduction of complex mechanical systems which reduce the energy required to satisfy this demand. Only after a thorough consideration of these steps should renewable energy generation be considered. The lower the energy demand of the building, the easier it is to achieve net zero in use.

Reducing energy demand of built assets reduces stress on grid infrastructure.
Lowering or eliminating the energy demand of new buildings will not only reduce the size and capital cost of plant equipment, but can subsequently reduce the cumulative stress applied to the national grid infrastructure. This is because there is a lower peak demand required and the load is likely to be more flexible due to the thermal stability of the building.

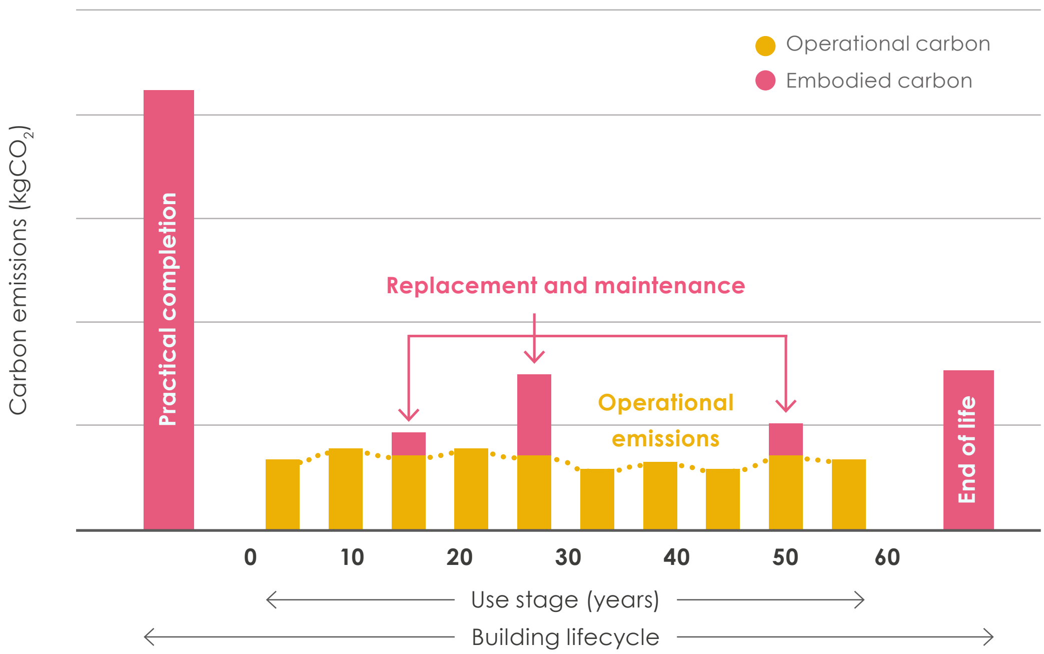


Figure 1.1 - Graph showing interaction between operational and embodied carbon throughout the lifetime of a building

1.2 Current challenges

Metrics: carbon and energy

The current UK regulatory framework within Approved Document L of the Building Regulations uses carbon emissions as the basis to determine compliance. There are a number of flaws/unintended consequences in using this methodology, most notably the carbon intensities of energy fuel supply adversely influencing on-site efficiency measures, and the neglect of building envelope efficiency in favour of mechanical systems' efficiencies. To address these issues, LETI believes that the operational energy of a building is the main metric that should be used, as this is likely to be relatively consistent through the building's lifetime.

Culture: design for compliance vs. performance

The UK national standard methodology for assessing energy compliance relies on a predefined set of assumptions and was created primarily for different building design proposals to be compared to one another. Whilst this method does form a level playing field for design proposals to be evaluated, it promotes a 'design for compliance' culture in which a short-term objective – compliance with regulations – is sought with little regard to how the building will actually perform in operation. The consequences of this approach are evident in much of our existing building stock, with operational performing much worse than anticipated at design. They achieve performance in theory but not in practice. The lack of feedback loops to communicate disparity between design and operation is considered to be one of the primary causes of the performance gap which is further discussed opposite.

Methodology: regulated vs. unregulated energy

Operational energy consumption is often categorised into two key components. 'Regulated' energy consumption results from controlled, fixed building services including heating and cooling, hot water, ventilation and lighting. 'Unregulated' energy consumption results from processes that are not covered by building regulations, i.e. ICT equipment, lifts, refrigeration systems, cooking equipment and other 'small power'.

One of the well documented shortcomings of the current Part L calculation methodology is its omission of unregulated energy loads. Although it can vary considerably by building type, unregulated energy can form up to 50% of total operational energy. The lack of consideration of unregulated energy at a regulatory level can lead to drastically different consumption to that estimated at the design stage.

Regulated loads:
→ Heating
→ Cooling
→ Hot Water
→ Lighting
→ Pumps and fans

Unregulated loads are plug loads such as:
→ Cooking
→ Appliances
→ TVs
→ Computers
→ Any other electrical equipment

Figure 1.2 - Regulated and unregulated energy

Operation: the performance gap - cause and effect

The performance gap is defined as the deficit between predictions of energy consumption from building compliance tools and actual measured energy use during operation. This determines whether a building and its systems work as expected when occupied, as well as the extent of the gap where not. Expectations for performance may be defined by regulatory targets or client requirements.

The causes of the performance gap have been found to be wide-ranging and complex, including many of the items listed above. Many of the contributory causes to the performance gap can be categorised into performance at three different stages: design, completion, and in-use. Independent research carried out by the UK Passivhaus Trust determined an average performance gap of 40% between the overall energy use of a new build house when compared to its EPC modelling and other evidence suggests that it can be up to 500%. In order to deliver a net zero built environment by 2050, it is therefore critical that this performance gap is closed.

Further information on the performance gap is provided in Appendix 1.2.

SIGNPOST *Appendix 1 - Operational energy*

Industry skills gap

One of the most significant barriers to adoption of high performance design and construction in the UK is the industry skills gap in delivering ultra-low energy buildings. While design professionals lack proficiency in design strategies and terminology, construction professionals and Building Control bodies do not fully understand their practical application. This often results in exaggerated capital cost estimates, typically attributed to two key aspects: achieving high levels of airtightness on site (including testing procedures), and additional site supervision and quality assurance.

LETI's experience suggests that these capital cost estimates are often inflated as a precautionary measure to absorb any additional time required for construction teams to undergo necessary training and any perceived risk. These cost uplifts have been found to correlate with building height due to the increasing importance of planning for optimal sequencing, as well as the narrowing choice of construction methodologies as the buildings increase in height.

1.3 Key components/ solutions (what?)

Achieving a net zero carbon built environment requires substantial reductions in energy demand from buildings, combined with decarbonisation of the electricity grid through an increase in the renewable energy contribution, as well as ensuring heat sources which are fossil fuel free.

LETI have taken a two-dimensional approach to establishing Energy Use Intensity (EUI) targets for each building archetype. A 'top-down' study of estimated future UK renewable energy generation is cross referenced with a 'bottom-up' analysis of best-practice design strategies for each building type. Whilst the 'bottom-up' approach focuses on 'the art of the possible', the 'top-down' modelling looks beyond the building boundary to what is likely to occur on a national scale — it effectively establishes a 'budget' for our energy demand.

This method ensures that the recommendations for achieving net zero carbon buildings not only take into account the expected national grid decarbonisation, but also reflect current technology and best practice energy conservation measures. LETI's basic premise is that to achieve a net zero operational balance, the EUIs developed via 'bottom-up' modelling must not exceed the budget established by 'top-down' analysis, i.e. the energy a building needs to operate must be matched by the amount of renewable energy that can reasonably be made available to that building in 2030 and ultimately in 2050.

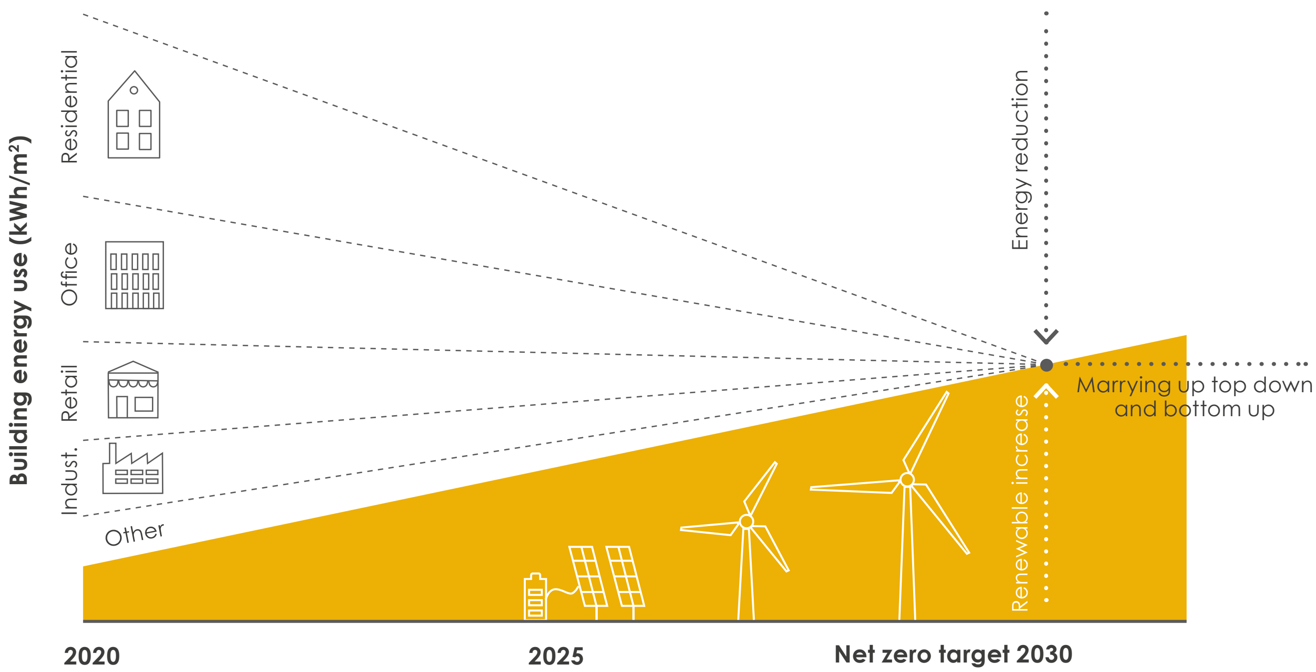


Figure 1.3 - Top-down meets bottom-up approach to energy

Top Down Modelling

To set energy budgets for each building archetype, LETI has compared the 2030 and 2050 forecasts for available renewable energy generation in the UK to the average total floor area of different building use types. By distributing available energy between building types in the same proportions as is seen today, a range of EUI 'ceilings' can be developed for domestic, office, retail and industrial buildings. The approach and data sources used for this calculation are outlined in further detail in Appendix 1.1.

SIGNPOST *Appendix 1 - Operational energy*

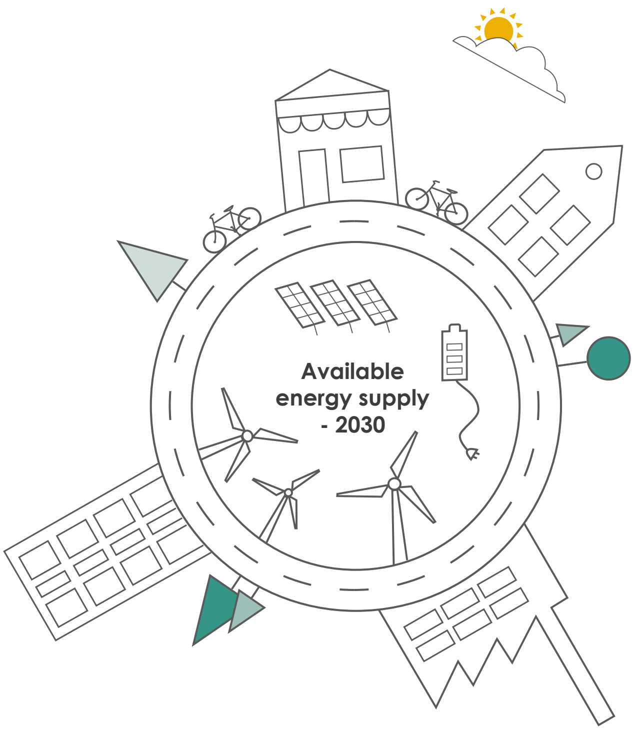


Figure 1.4 - Top down method

Bottom Up Modelling

The current Part L methodology of setting targets using a percentage reduction in emissions from a notional equivalent building means that neither the energy demand of proposals nor the potential of better design, fabric and equipment performance are well understood.

LETI has therefore modelled the theoretical energy demand of different building archetypes, varying key design parameters to determine the realistically achievable EUIs and arrive at a set of 'optimised' designs. The archetype-dependent design parameters include form factor (efficiency of shape), glazing ratio, fabric performance, ventilation type and heating/cooling equipment performance.

These design parameters have been set at values which LETI considers to be achievable and realistic. Perhaps surprisingly, while the parameters largely go beyond the current Building Regulations minima, they are not significantly better than many of buildings currently being designed.

Modelling has established 'best-practice' or 'optimised' EUIs, which indicate the lowest energy demand for each archetype that LETI considers to be realistically achievable given the technologies and materials available to designers over the next decade.

Setting the Targets

Having looked at the problem from both the 'top down' (likely available energy budget) and 'bottom up' (what we can actually achieve), LETI has set a series of EUI targets for different building archetypes. In setting these targets, LETI has taken into consideration factors such as:

→ Where we are now – the energy demand of our current new builds
→ Best practice right now and what exemplary schemes are achieving
→ The scope for further fabric improvements in new buildings – beyond best practice and towards exemplar
→ Potential incremental improvements in technology (e.g. Heat Pump COPs), adoption of waste water heat recovery systems
→ Potential for the deployment of more renewable technology, at a national scale, as a result of the Climate Emergency – i.e. an increase in the available 'budget'
→ The challenge and magnitude of retrofitting existing buildings and their demand for renewable energy – i.e. we will not be able to retrofit existing buildings to the same levels of fabric efficiency and so we need to accept that they will need to take a disproportionate share of the 'budget'

To illustrate this process for the domestic sector, the chart below shows what LETI believes to be the current average EUI of new dwellings, best practice, exemplar schemes and the top-down budget, set against these is what LETI believes to be an achievable and pragmatic target for our new dwellings from 2030.

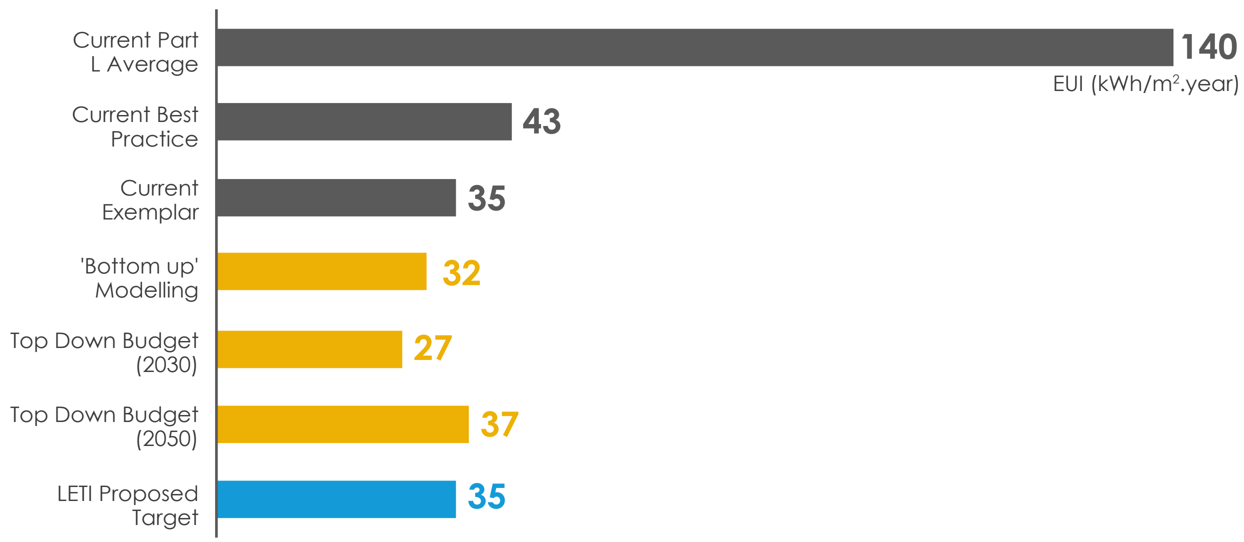


Figure 1.5 - Deriving the LETI residential EUI target

LETI's energy use intensity (EUI) targets for each archetype are as follows:

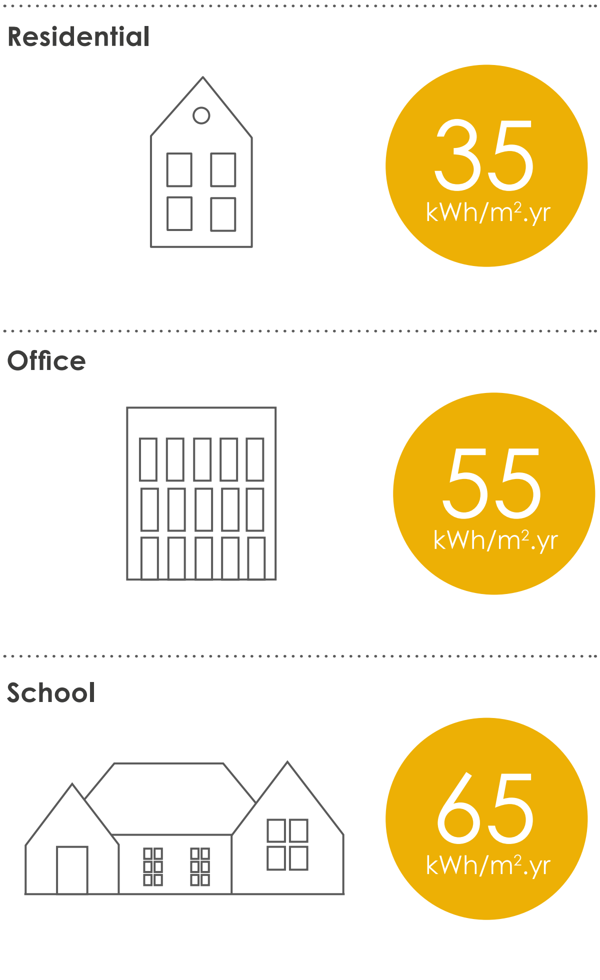


Figure 1.6 - LETI EUI targets

EUI targets above are based on GIA areas and exclude renewable energy contribution.

What does a 'Best Practice' building look like?

The modelling LETI has undertaken shows that low-energy buildings would fundamentally change the energy breakdown of our built environment. For residential buildings, space heating tends to require most energy due to relatively poor fabric standards. A highly efficient fabric reduces this significantly.

The diagrams below show how LETI's best-practice parameters affect the overall amount and breakdown of the energy demand in a typical domestic dwelling.

The concept of 'shoebox' modelling refers to the creation of a simplified energy model to inform decision making at concept design stage. A model of this type can take the form of a simple shoebox and can be carried out prior to any formal design work. The process can provide valuable information on the proposed building's energy characteristics, reveal its sensitivity to different design variables and help identify the 'low hanging fruit' of energy saving measures.

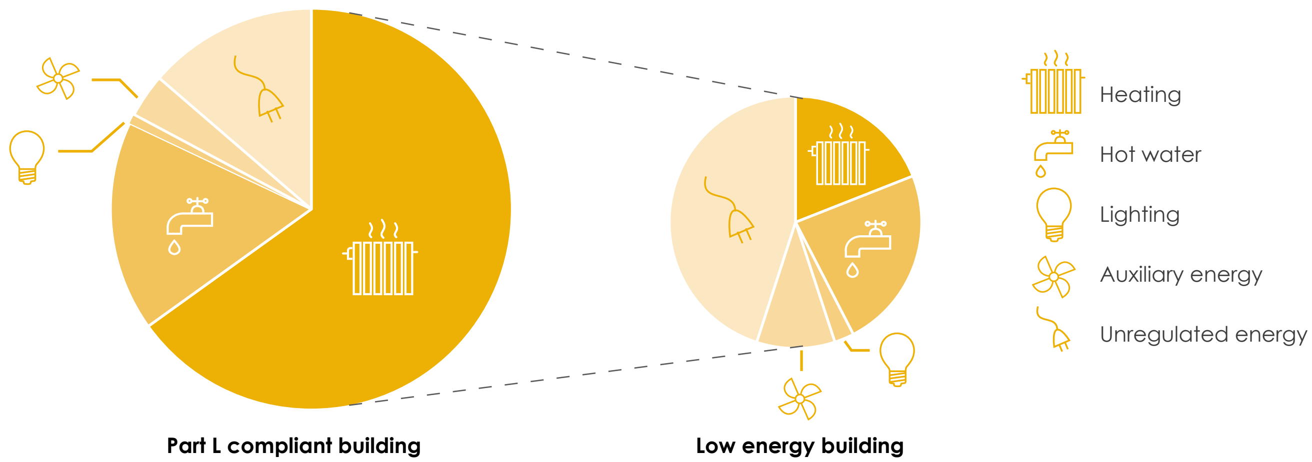


Figure 1.7 - Residential energy breakdown

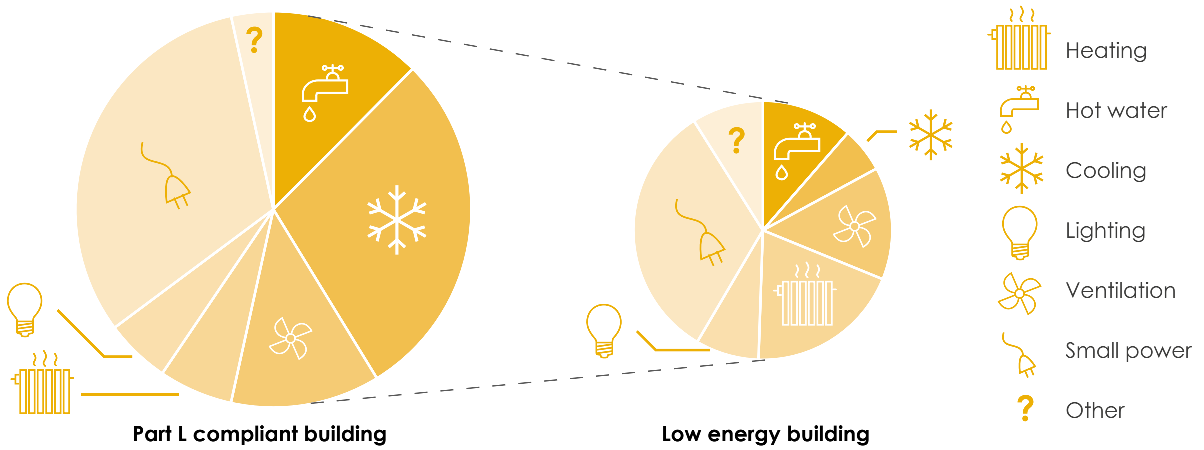


Figure 1.8 - Office energy breakdown

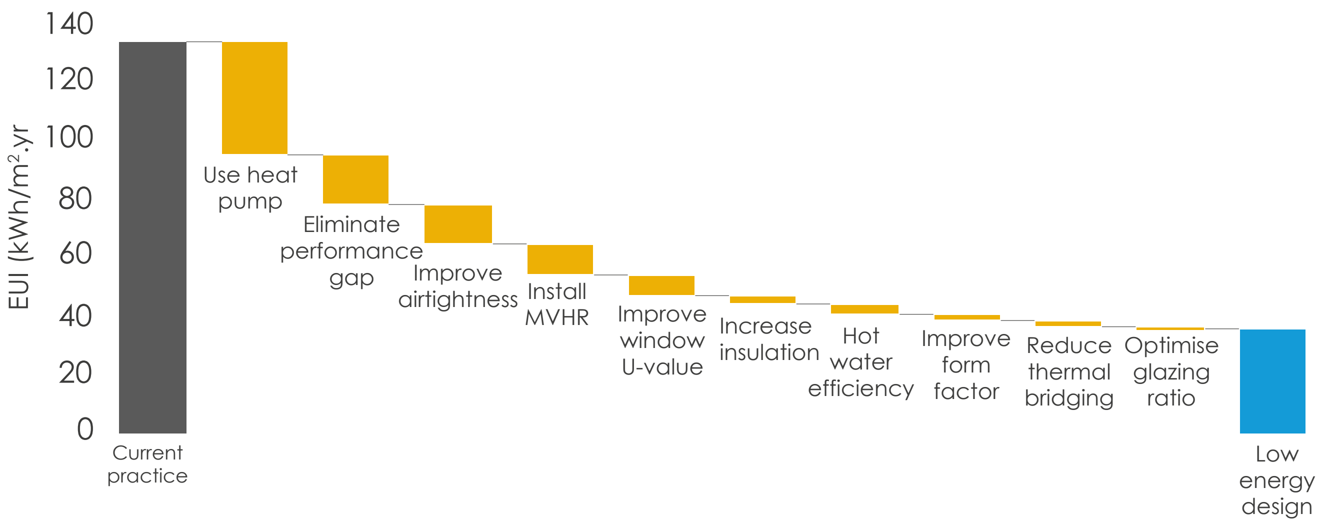


Figure 1.9 - Opportunities to reduce energy consumption in a new residential development

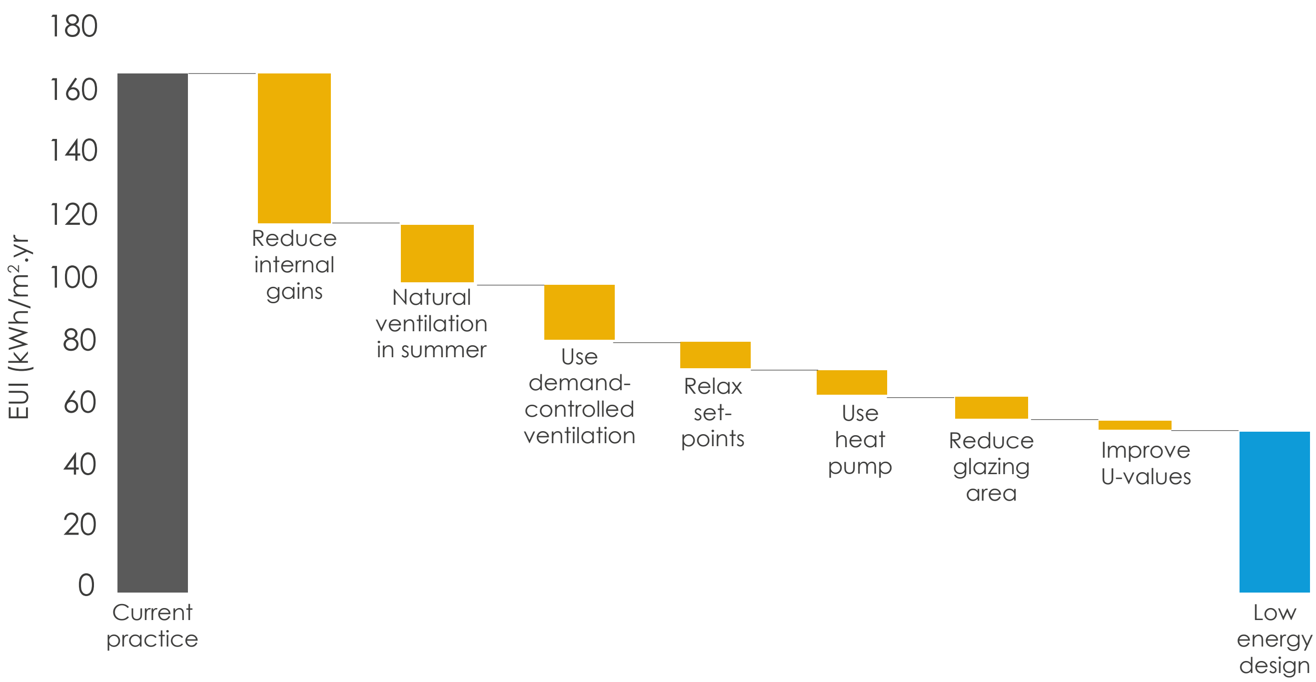


Figure 1.10 - Opportunities to reduce energy consumption in a new commercial office development

What does 'fabric' mean and what is important?

The building 'fabric' is made up of the materials that make up walls, floors, roofs, windows and doors. The more insulation contained within these elements, the better their thermal performance. However, 'fabric' also includes the building's overall airtightness, as well as the impact of thermal bridges where the insulation layer is not continuous.

Why concept design is critical

The specification of the fabric, materials and HVAC systems will all have a significant impact on the energy demand of a building. However, even more fundamental are some key design decisions which are typically shaped very early on. These are orientation, form factor and glazing ratio.

A building's orientation combined with its glazing ratio is key to minimising energy demand. In the UK over the course of a year, North facing windows nearly always lead to net heat loss, whereas south facing ones can normally be designed to achieve a net heat gain. However, the amount of South facing glazing should also be optimised to prevent the risk of summer overheating. Although East/West windows can provide useful gains, they can often lead to overheating due to the low angle of the sun at the start/end of the day.

The optimum glazing ratios for the UK climate are up to 25% glazed on the southern elevation, no more than 20% on the East/West elevations and as little as possible on the Northern elevation. The diagram below shows the impact on space heating demand as the same building is rotated to place its originally south facing glazing in a northerly direction. It shows that purely by changing the building's orientation, the space heating demand increases from 13kWh/m^2.yr to 24kWh/m^2.yr.

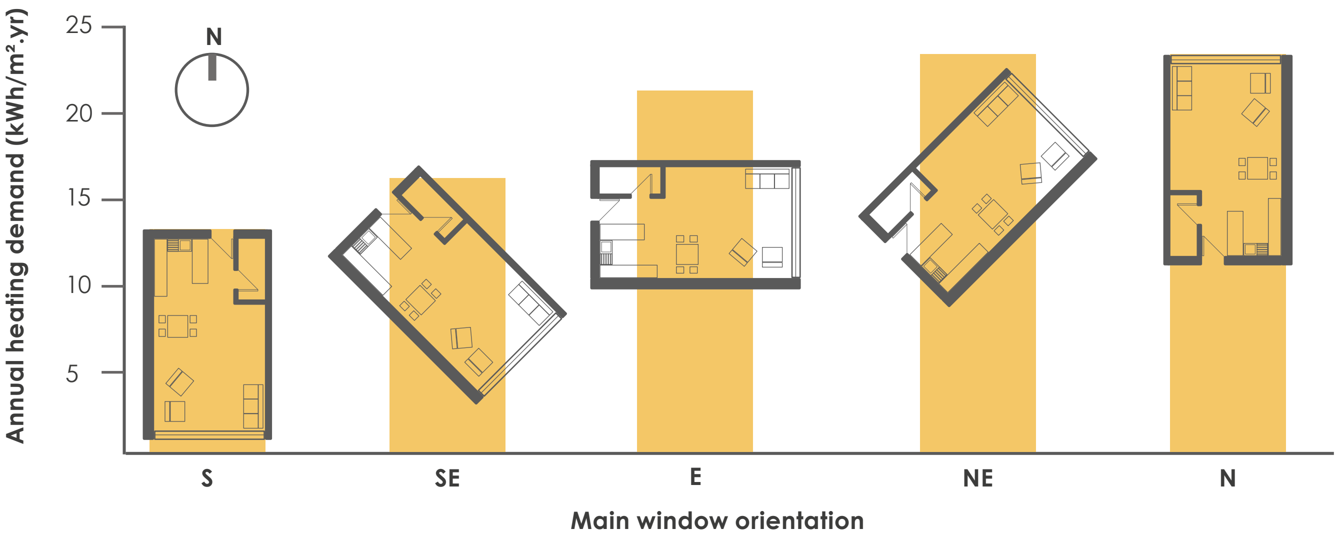


Figure 1.11 - Why orientation is important

A building's form factor is the ratio of its external surface area (i.e. the parts of the building exposed to outdoor conditions) to the internal floor area. The greater the ratio, the less efficient the building and the greater the energy demand. Detached dwellings will have a high form factor, whereas apartment blocks will have a much lower form factor and thus will tend to be more energy efficient. The table below shows the typical form factors associated with different design configurations.

If a building is designed with a poor form factor, then the fabric efficiency will need to be increased significantly to achieve the optimum levels of performance. This will increase costs as more insulation and more efficient systems will be required.

Type	Form factor	Efficiency
Bungalow house	3.0	Least efficient
Detached house	2.5	
Semi-detached house	2.1	
Mid-terrace house	1.7	
End mid-floor apartment	0.8	Most efficient

Figure 1.12 - Types of homes and their form factor

1.4 Implementation mechanisms (how?)

Regulatory reform

The first and most important step in achieving a net zero built environment is to set out regulations which are clear, measurable and indicate a pathway to 2030:

→ The 'notional building model' should be replaced with a series of absolute Energy Use Intensity (EUI) targets in kWh/m^2.yr for space heating, hot water and overall energy demand at the meter.
→ Building performance should be measured in terms of energy rather than carbon as changing carbon factors constantly move the goalposts.
→ In addition to an enhanced compliance regime, actual performance measurements and post-completion compliance declarations should form part of future regulations, so that the industry can start working towards closing the performance gap.
→ Clear future energy targets for both retrofit & new build from 2020 through to 2030 are required, to enable the industry to prepare and adjust.
→ Developers choosing to build to higher standards should be rewarded.
→ Mechanical Ventilation with Heat Recovery (MVHR) should be the default ventilation system in all new buildings, to reduce heat loss through ventilation and improve indoor air quality.
→ Local Authorities should be allowed and encouraged to go beyond statutory building regulations and set energy consumption limits.
→ To ensure robust and cost-effective routes to net zero carbon, energy efficiency measures should be prioritised over on-site renewables.

Establishing a zero carbon training and research centre

In order to facilitate the dissemination of knowledge and accelerate the adoption of net zero carbon building in the UK by 2030, LETI recommends the establishment of a dedicated training and research centre. The Zero Carbon Hub (http://www.zerocarbonhub.org/) provided a valuable resource to the construction industry between 2008-2016 until funding was cut when the Zero Carbon Homes policy was abandoned.
LETI recommends the re-establishment of an industry training and research centre focused on the delivery of net zero carbon buildings, with four key objectives:

→ Provide a collaborative platform that strengthens the understanding and capacity for zero carbon buildings in the UK.
→ Provide an industry support hub that facilitates exchange of best practice knowledge, towards sustained market transformation.
→ Deliver a curriculum of industry workshops and events, focused on enhancing understanding and application of high-performance design and construction.
→ Become a trusted industry resource for design and construction professionals, and carry out independent research to identify challenges and effective solutions associated with zero carbon performance.

1.5 Case studies

Office – Enterprise Centre, Norwich, EUI 70 kWh/m^2.yr

The Enterprise Centre project inception started in 2007, with InCrops. Funding was secured in 2011, the ground breaking ceremony took place in November 2013, and the low carbon concrete base was poured in July 2014. The building demonstrates the use of different, low carbon materials in construction, and the potential for local materials in the Norfolk and East Anglian region.

The Enterprise Centre was developed and built to the Passivhaus standard, which is recognised as the most stringent low 'energy in use' standard. It moves beyond UEA's previous low carbon buildings through improved insulation, an improvement in air tightness and there are strong controls on the energy used within the building. The triple-glazed windows and the building's orientation maximise natural light and minimise heat loss. It has also achieved BREEAM Outstanding with a score of 93%, a holistic measure of a building's attention to sustainable measures.

Figure 1.13 - The Enterprise Centre
Source: Architype

Domestic – Lark Rise, EUI 32 kWh/m^2.yr

Lark Rise is an all-electric, two-bedroom guest house designed to the Passivhaus Plus standard located on a north-west facing slope on the edge of the Chiltern Hills in Buckinghamshire. The project was completed in 2015. The building has an exceptionally low heating demand achieved by an efficient form factor and high fabric standards. This includes mechanical ventilation with heat recovery. A large photovoltaic array means that, over the course of a year, the building generates twice as much energy as it consumes.

Figure 1.14 - Lark Rise
Source: Bere:Architects

2

Embodied carbon

Key performance indicators

1

Meet upfront embodied carbon emission targets for building elements:

	Baseline	Best practice 2020	Best practice 2030
Domestic	800 kgCO_2/m^2	<500 kgCO_2/m^2 Equiv. to 40% reduction over baseline **30%** materials from re-used sources **50%** materials can be re-used at end of life	<300 kgCO_2/m^2 Equiv. to 65% reduction over baseline **50%** materials from re-used sources **80%** materials can be re-used at end of life
Non-domestic	1000 kgCO_2/m^2	<600 kgCO_2/m^2 Equiv. to 40% reduction over baseline **30%** materials from re-used sources **50%** materials can be re-used at end of life	<350 kgCO_2/m^2 Equiv. to 65% reduction over baseline **50%** materials from re-used sources **80%** materials can be re-used at end of life

2

Upfront embodied carbon emissions to be verified post-construction.

Building element targets include products, transport and construction of substructure, superstructure, MEP, façade and internal finishes (A1-A5).
Figures exclude timber sequestration.

Summary

Client/Developer (decision making)

→ Clarify the client's goals for Net Zero and Circular Economy developments that embrace embodied carbon reductions.
→ Develop financial structures within the developer's business for allocating funds across R&D/pilot projects.
→ Identify employees across the client's business who will be responsible for Net Zero, circularity and embodied carbon performance outcomes.
→ Specify in the project brief that the development will have low embodied carbon, adopting the principle of reuse and refurbish over new build and requiring a comprehensive embodied carbon reduction strategy.
→ Stipulate embodied carbon performance targets.
→ Appoint a design team (consultant and contractor) with experience of conducting embodied and whole life carbon analysis.
→ Specify in the contract that the principal contractor will monitor and report 'as-constructed' embodied carbon showing compliance with embodied carbon performance targets.

Policymaker (strategy)

→ Adopt a policy hierarchy that advocates circular economy principles: reuse and refurbishment in preference to demolition and new construction.
→ Adopt a policy that mandates embodied carbon reduction strategies based on embodied carbon and whole life carbon analysis on all projects.
→ Adopt embodied carbon targets.
→ Recognise a consistent methodology and dataset for embodied and whole life carbon analysis e.g. Royal Institution of Chartered Surveyors (RICS) Professional Statement Whole Life Carbon, reporting embodied carbon across the chosen Life Cycle Stages of EN 15978, as explained in Appendix 2.1 Embodied Carbon Reduction Calculations.
→ Phasing in the mandatory requirement of EPDs for at least all building parts forming substructure, frame and upper floors.

Designer (implementation)

→ Adopt the circular economy principle of reuse and refurbish before new build ('retro first').
→ Upskill the design team to develop in-house capabilities and understanding of embodied and whole life carbon reduction principles and 'big wins', to recognise where the largest reductions in embodied carbon can be made.
→ Implement embodied carbon as a sustainable design metric and calculate embodied carbon emissions of all projects.
→ Request Environmental Product Declarations (EPDs) from all suppliers.

SIGNPOST *Appendix 2 - Embodied carbon*

2.0 Introduction

This chapter offers easy-to-follow guidance for clients, designers and policy-makers to better understand how embodied carbon can be reduced in the design and construction of buildings.

It is not intended to be an all-encompassing guide to embodied carbon due to the nature of emerging knowledge in this field and should always be read in conjunction with latest guidance and technical toolkits available, such as those by the UKGBC, RICS and the RIBA, as listed in Appendix 14 of the Embodied Carbon Primer.

SIGNPOST *Embodied Carbon Primer*

Embodied Carbon: Carbon dioxide and other greenhouse gases are associated with the following stages:

→ **Product:** extraction and processing of materials, energy and water consumption used by the factory and transport of materials and products.
→ **Construction:** building the development.
→ **In-use:** maintenance, repair, refurbishment, replacement and emissions associated with refrigerant leakage.
→ **End of life:** demolition, disassembly waste processing and disposal of any parts of product or building and any transportation relating to the above.

See Appendix 2.1 for the EN 15978 detailed breakdown of stages.

SIGNPOST *Appendix 2 - Embodied carbon*

Operational Carbon: Please refer to Chapter 1 Operational Energy which explains operational carbon.

SIGNPOST *Chapter 1 - Operational energy*

Whole life carbon (WLC): This includes both embodied carbon, as defined above, and carbon emissions associated with operational energy. The purpose of using WLC is to move towards a building or a product that generates lowest carbon emissions over its whole life (sometimes referred to as 'cradle-to-grave'). Figure 2.1 shows the building life cycle stages, and Figure 2.2 shows the interaction between operational and embodied carbon throughout the lifetime of a building.

Life cycle assessment (LCA): A multi-step procedure to quantify carbon emissions (embodied and operational) and other environmental impacts (such as acidification and eutrophication) through the life stages of a building. The EN 15978 standard is typically used to define the different life cycle stages A1-3 ('Cradle to Gate'), A1-3 + A4-5 ('Cradle to Practical Completion of Works'), B1-5 ('Use'), C1-4 ('End of Life'), D ('Supplemental'), see Figure 2.1.

In the case of whole life carbon, an LCA assesses greenhouses gas emissions measured in carbon dioxide equivalent to also include Global Warming Potential (GWP).

Thus the use of predicted CO_2 data across the Life Cycle Stages relevant to the particular development allows comparisons of different options in relation to impact on whole life carbon as well as demonstrating that a certain level of carbon emission reductions have been met at design stage[1].

Environmental Product Declaration (EPD): An independently verified and registered document that communicates transparent and comparable information about the life cycle environmental impact of a product[2].

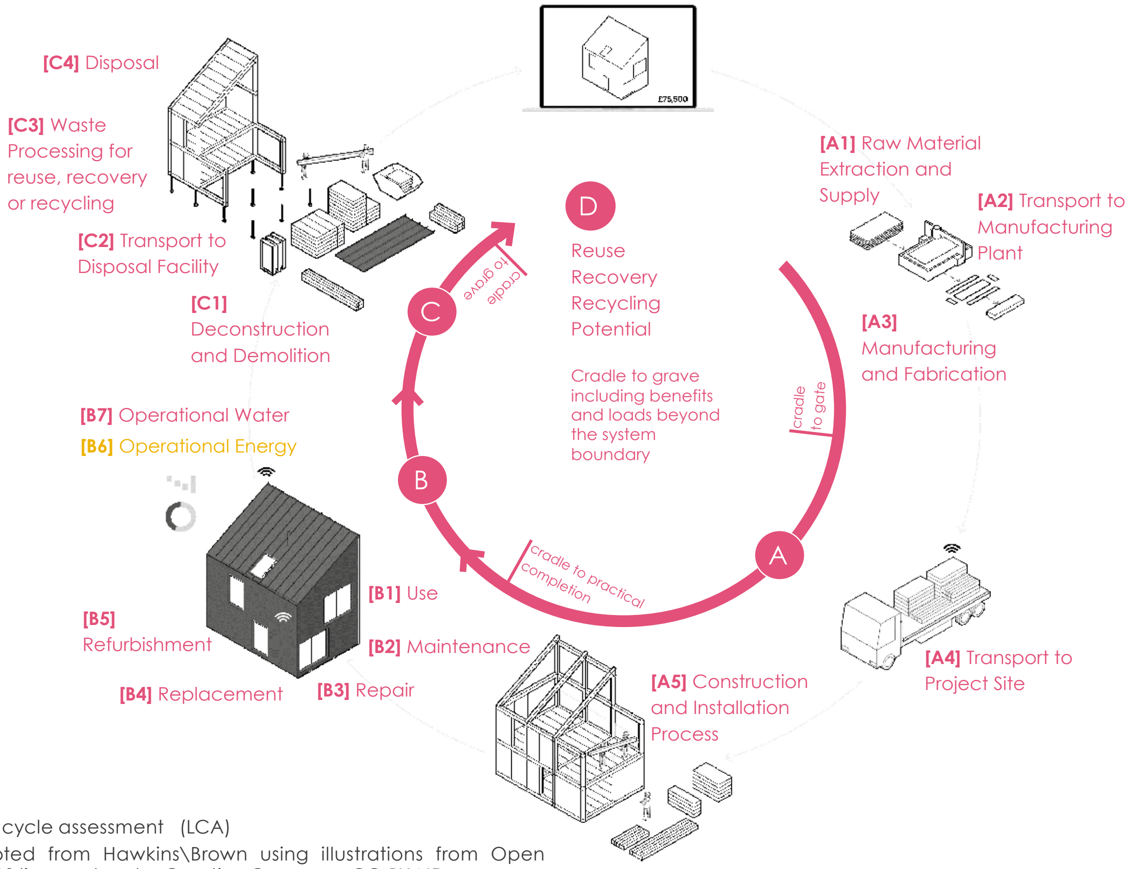


Figure 2.1 - Life cycle assessment (LCA)
Diagram adapted from Hawkins\Brown using illustrations from Open Systems Lab 2018 licensed under Creative Commons CC-BY-ND

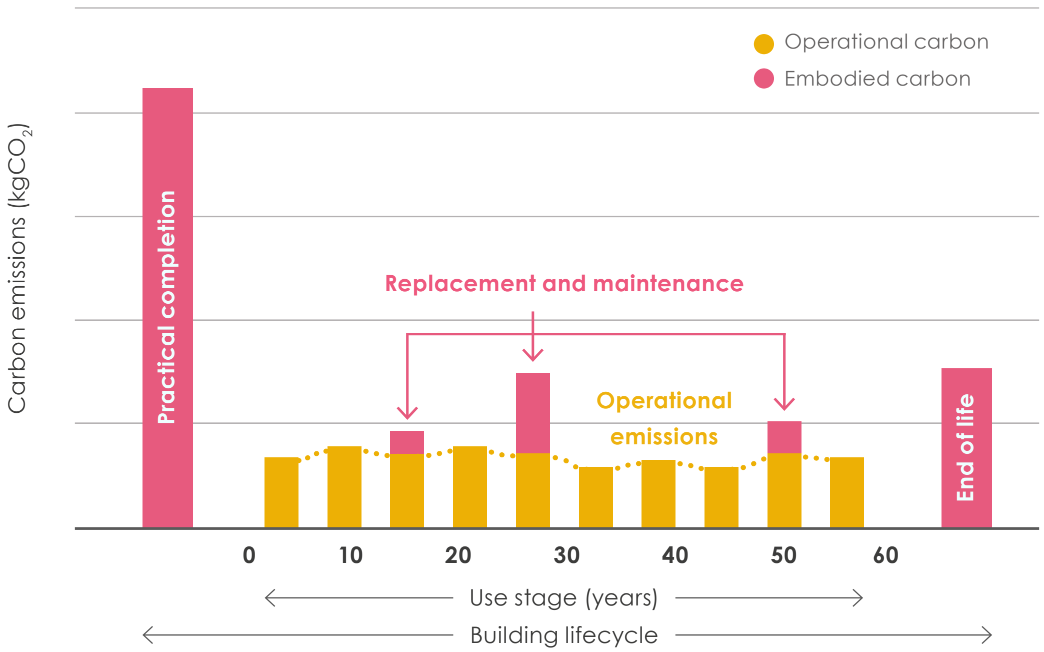


Figure 2.2 - Graph showing interaction between operational and embodied carbon throughout the lifetime of a building

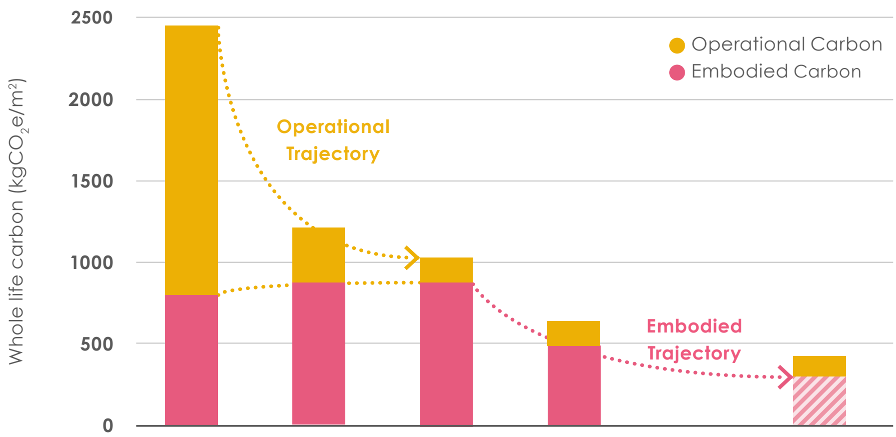
2.1 Contribution to zero carbon (why do it?)

In the UK, buildings account for 49% of greenhouse gas emissions. Of the annual carbon emissions associated with buildings about 80% is associated with ongoing operational carbon emissions relating to the existing building stock. The remaining 20% is related to the embodied impact of new construction.

Addressing climate change has traditionally focused on reducing carbon emissions from operational energy consumption. However, as buildings become more energy efficient and electricity generation decarbonises, operational carbon of new buildings will significantly reduce. This means that embodied carbon will represent a higher proportion of whole life carbon (WLC) than it used to. Thus embodied carbon will become significant and can represent 40-70% of whole life carbon in a new low carbon building. See Figure 2.3 that shows the magnitude and breakdown of whole life carbon.

Figure 2.4 shows the breakdown of the whole life carbon stages of an office, residential development and a school. The pie charts to the left show the breakdown when the development is built to current Building Regulation levels, in this case the operational energy makes up by far the largest proportion of whole life carbon. The pie charts to the right shows the breakdown of whole life carbon when the development is ultra-low energy (the standard that is set out in the operational energy requirements in the archetype pages in the introduction). Due to the reduction in operational energy, the product stage (A1-A3) makes up the largest proportion of whole life carbon.

SIGNPOST *Chapter 0 - Introduction*



Operational Carbon Scenario	Current Building Regulations	Ultra-low energy with Gas Boiler	Ultra-low energy with Heat Pump	Ultra-low energy with Heat Pump	Ultra-low energy with Heat Pump
Embodied Carbon Scenario	Not considered	Not considered	Not considered	Embodied Carbon Reductions	Future Embodied Benchmark

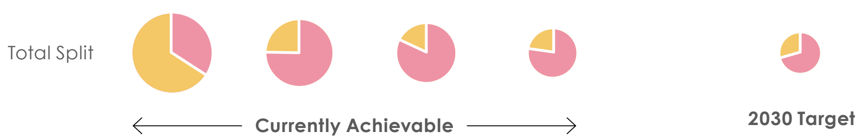


Figure 2.3 - Diagram showing operational and embodied carbon and trajectories

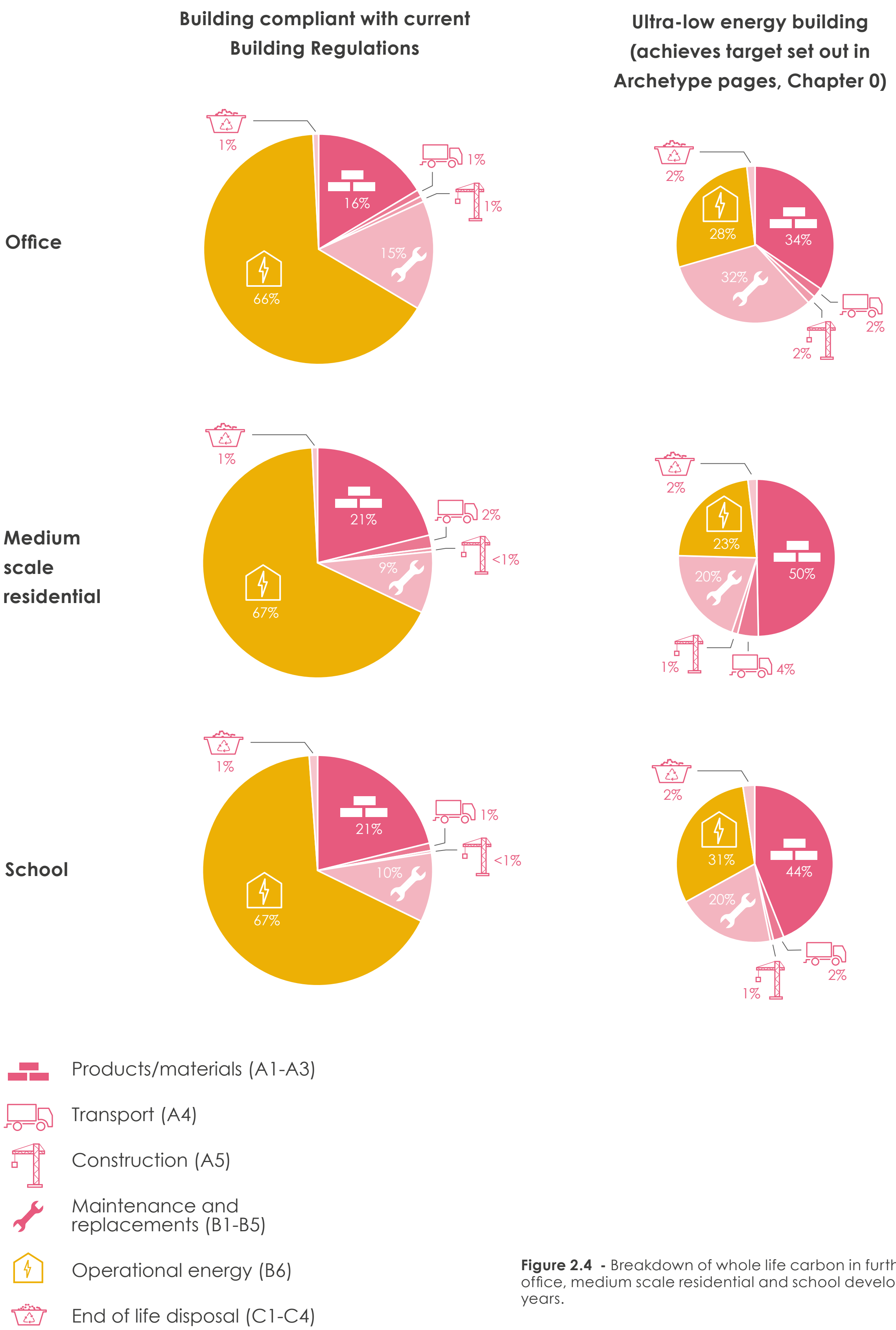


Figure 2.4 - Breakdown of whole life carbon in further detail for typical office, medium scale residential and school developments over 60 years.

2.2 Current challenges

To date, most of the focus has been on reducing operational carbon emissions. As a result, the development of embodied carbon calculations has lagged. The first challenge, therefore, is to improve industry understanding of embodied carbon, and then to focus on the elements that represent the largest contribution within a building project.

Other challenges include:
→ Lack of information and transparency on materials in products
→ Lack of consistency of methodology for calculating embodied carbon
→ Lack of available data from case studies

2.3 Key components/ solutions (what?)

This section identifies clear actions that can be taken to reduce the embodied carbon of a building and its constituent elements. Primary actions are shown in Figure 2.6 aside and Figure 2.8 overleaf summarises the overarching aims and approaches for different building elements, set out in the embodied carbon Primer Appendix 6 - Rules of Thumb.

SIGNPOST *Embodied Carbon Primer - Appendix 6*

Aims and Approach:
1. **Build less**: Refurb and re-use
2. **Build light**: Consider the building structure
3. **Build wise**: Longevity and local context
4. **Build low carbon**: Review material specifications
5. **Build for the future**: Assess end of life and adaptability
6. **Build collaboratively**: Involve the whole team

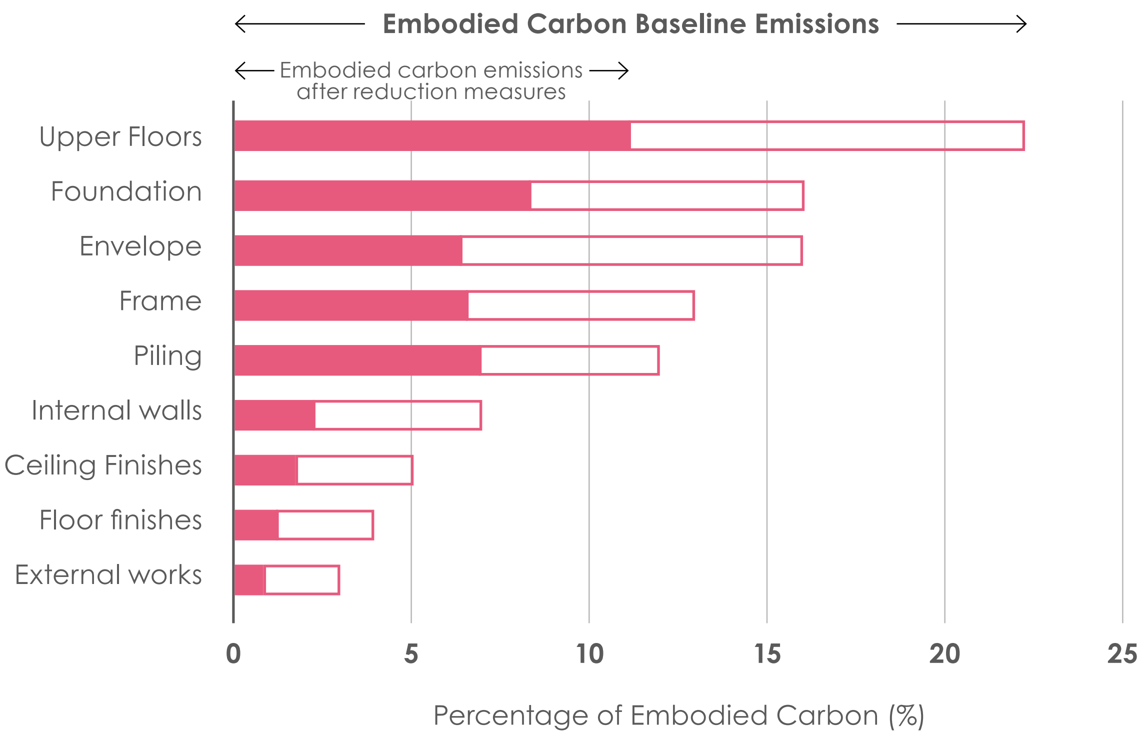


Figure 2.5 - Illustrative Embodied Carbon reduction potential (Study by Mirko Farnetani)

Primary Actions

Build less

- → Is a new building necessary to meet the brief, has retrofit been considered?
- → Can existing materials on or near the site be used?
- → Has the brief been interrogated against client need and represents the most efficient solution?
- → Can uses be shared or spaces be multi-functional?
- → Carry out a material efficiency review - are all materials proposed necessary?
- → Seek to simplify the design - simple designs usually means less embodied carbon.

Build light

- → Reduce the weight of the dead loads where possible.
- → What loadings are really required to meet the brief?
- → Can long spans be restricted?

Build wise

- → Ensure longevity of material and systems specifications.
- → Review material efficiency options like designing to standard building sizes or for a repeating module.
- → Structural members should be designed for 100% utilisation rate where possible.
- → Analysing a site is an important activity at the start of a project and this can be extended to the identification of ways of reducing embodied carbon. Possible opportunities include:
  - → There may be existing structures or buildings that can be reused or become a source of recycled materials.
  - → There may be locally sourced material options, reducing transport to site while allowing architectural expression of the context.
  - → Designing a project around a site topography, reusing excavated soil and reducing the amount removed from site.

Build low carbon

- → Reduce the use of high embodied carbon materials.
- → Identify 'Big ticket Items' and focus on the big wins first including structure and envelope.
- → Consider natural and renewable materials.
- → Explore Design for Manufacture and Assembly (DfMA) solutions if this reduces embodied carbon.

Build for the future

- → Ensure future uses and end of life are considered and adaptability is designed in.
- → Consider soft spots in the structure.
- → Consider regular structural grid and future-proofed risers and central plant space.
- → Mechanically fix systems rather than adhesive fix so they can be demounted and re-used or recycled, supporting a circular economy.
- → Explore methods of creating longevity for materials without additional coatings, as they can reduce the recyclability of the material.

Build collaboratively

- → Solutions must involve the whole design team and the client.
- → Use 'rules of thumb' data to drive decision making in meetings, especially in the early stages of design.

Figure 2.6 - Primary actions to reduce embodied carbon for a whole building

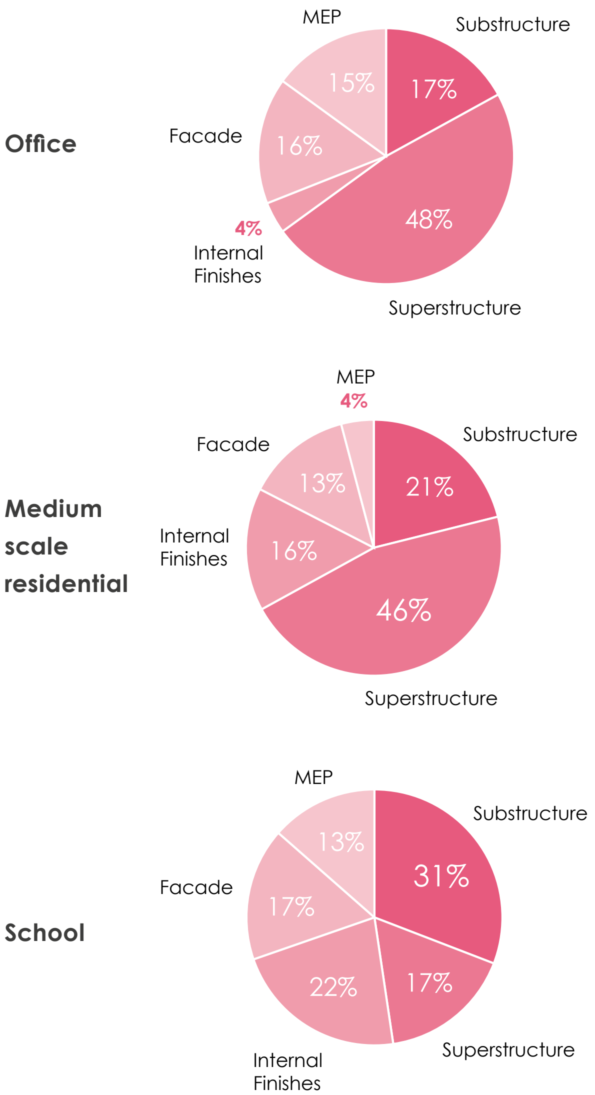


Figure 2.7 - Embodied Carbon breakdown per element (Cradle to Gate).

Proportions of embodied carbon by building element

Figure 2.7 shows the relative proportions of embodied carbon by building element.

It is important to consider not just the proportion of embodied carbon per element, but also the potential total embodied carbon reductions of all the elements. At RIBA Stage 3 a detailed whole life carbon study shall be undertaken. As part of this, a study shall be undertaken that identifies the breakdown of embodied carbon by element and the carbon reductions that could be achieved for each element. This helps to identify 'big ticket items' – where the greatest embodied carbon reductions can be achieved.

Figure 2.5 (on the previous page) is an example of the results of this type of assessment for a typical mixed used development (commercial and residential). It is evident that the top five building parts (Piling, Foundation, Frame, Upper Floor and Envelope) provide the greatest embodied carbon reduction opportunities and thus should be the focus. Nevertheless, the remaining bottom items (ceiling finishes, internal walls, floor finishes and external works) should also be considered for establishing the project embodied carbon reduction strategy.

Figure 2.8 showcases 'rules of thumb' for reducing embodied carbon by building element and identifies areas where a large benefit can be found, this is a summary Appendix 6 of the LETI Embodied Carbon Primer.

SIGNPOST *Embodied Carbon Primer - Appendix 6*

Reductions to embodied carbon by element

Structure (Sub and super structure)	→ Compare the embodied carbon options for sub and superstructure at an early stage to identify an optimum solution. → Typical bay studies for the horizontal and vertical grid should be conducted at concept stage for different material arrangements to determine the impact on the total embodied carbon for each framing arrangement. → A structural rationalisation study should be conducted to determine the impact on overall material quantity versus efficiency in construction/fabrication. → Reduce the weight of structure where possible through voids. → Maximum embodied carbon quantities should be specified for structural components. Targets can be achieved by cement replacement such as GGBS, low carbon concrete mix design, low carbon materials and using recycled/repurposed materials. → Structural frame should be considered to have a dual purpose, i.e. the structure could serve as a shading device rather than introducing additional shading elements to control solar gain. → Explore recycled sources of material.
Envelope (Facade and roof)	→ Carry out embodied carbon comparisons on typical construction bays during early design stages where decisions can be guided by benchmarks / data. → Remember that it is the hidden parts (for example metal secondary framing) of a build up that often contain the most embodied carbon. → Where metals are used, limit their use and ensure they can be removed and recycled at end of life.
Mechanical, Electrical and plumbing (MEP)	→ Avoid over-provision of plant - a detailed load assessment must be undertaken. → Typically, fewer and simpler systems will reduce embodied carbon. → Explore options for plant room locations which reduce duct runs. → Design for deconstruction and recycling as MEP is typically replaced 2-3 times during the lifespan of a building. → Specify refrigerants with low Global Warming Potential (i.e. <150) and ensure refrigerant leakage is carefully considered in the whole life carbon analysis.
Finishes and Furniture Fixtures and equipment (FF&E)	→ Consider eliminating materials where not needed e.g. by exposing services. → Utilise self-finishing internal surfaces like timber. → Consider the cleaning and maintenance regime to be undertaken. → Ensure the fit out requirement is clearly understood to avoid FF&E to be replaced when the first tenant moved in. → Carefully compare products based on EPD data, recycled material and also avoidance of harmful chemicals like formaldehydes and VOCs. → Consider the replacement cycle and specify for longevity. → Choose products that do not rely on adhesives so fabrics or finishes can be replaced. → Be wary of trends that are likely to date and require early replacement.
Design for Manufacture and Assembly (DfMA)	→ Compare embodied carbon of DfMA solutions with standard solutions. → If DfMA is to be used, identify the elements by the end of RIBA Stage 2. Examples include, bathroom or WC pods, plant modules, facade elements, repeatable rooms, pre-fabricated structural elements including twin wall, columns and planks. → Engage the supply chain early. → Lightweight materials are preferable for transportation purpose. → Ensure the repeatable systems are designed for deconstruction.

Figure 2.8 - Primary actions to reduce embodied carbon for each building element

2.4 Implementation mechanisms (how?)

Advice for designers

Appendix 1 of the Embodied Carbon Primer discusses in more detail how the designer can make low embodied carbon strategies most attractive to clients and lays out the crucial times to frame these within the project:

→ **The first meeting:** Understanding project priorities such as low cost, long-term ownership/ maintenance.

→ **When being appointed:** Ensure that carbon analysis is integrated into the scope of services and the design programme as well as allowing for any associated fees for consultants. Key discussion points with the client can include: secondary benefits of reducing carbon, New London Plan, BREEAM and LCA.

→ **When looking to reduce construction costs (value engineering):** Weigh up design aspirations with core low carbon strategies and material quantity/ quality considerations, especially in relation to maintenance. Look at the latest technologies and systems for opportunities to reduce costs.

→ **When the building is completed:** Post-construction evaluation is key to building knowledge and making improvements. Ensure appointments allow for this.

SIGNPOST *Embodied Carbon Primer - Appendix 1*

Procurement

LETI believe that public procurement, responsible for 25% of all UK construction procurement annually, should lead the way for best practice nationally. The legal framework for public procurement (particularly Public Contracts Regulations 2015) is explicit that 'all public procurement must be based on value for money, defined as "the best mix of quality and effectiveness for the least outlay over the period of use of the goods or services bought". However designers and industry experts suggest that a life-cycle approach is rarely undertaken.

Procurement should ensure that carbon becomes a measurable aspect of the specification, such that however the building is constructed, carbon forms part of the contractual obligation of those designing and building it.

The form of procurement impacts the agency of the designer in maintaining low carbon strategies, and different forms of procurement will prioritise different aspects, e.g. cost, time, quality, risk, finance etc. It is useful to align carbon reduction strategies to other project priorities. Appendix 5 of the Embodied Carbon Primer contains a table of suggestions of low carbon strategies associated with the procurement priorities listed above.

SIGNPOST *Embodied Carbon Primer - Appendix 5*

Details on Implementation mechanisms for policy makers

→ Create a national embodied and whole life carbon database (e.g. the Dutch Nationale Milieudatabase) in support of planning policies mandating embodied and whole life carbon assessment.
→ Review the procurement framework awarding criteria for public buildings and infrastructure, to incorporate embodied and whole life carbon targets and wider social/economic responsibility in terms of life cycle costs within the scoring system.
→ Include requirements on embodied and whole life carbon in building planning and approval frameworks with consent contingent on the subsequent reporting of performance against the design stage target.
→ Mandate a two-fold verification system: at the Design Stage and at Practical Completion Stage. This would build on planning policies that mandate embodied and whole life carbon assessment and adoption of target benchmarks.
→ Adopt planning policy that requires Environmental Performance Declaration (EPDs) for the majority of building parts forming substructure, frame and upper floors.

2.5 Case study

Hub 67 - LYN Atelier

'Hub 67' is a temporary community centre made from material collected in shipping containers left after the London Olympics 2012. LYN Atelier won the bid from the Olympic Delivery Authority to deliver a project made from re-used building components for a sum of £350,000. The main structure of the community centre was constructed from glazed and insulated composite metal panels salvaged from the banks and food vending machines from the Olympic grounds.

The main challenge was the complete lack of information on the performance criteria (thermal and other) of the materials. This approach relied heavily on the experience and expertise of the designers and construction team, who were required to declare the reformulated construction systems 'fit for purpose' in the absence of any manufacturer certification or guarantees.

Figure 2.9 - Hub 67
Source: Re-use Atlas Duncan Baker Brown

2.6 References

1 - Athena, Sustainable Material Institute definition
2 - Environdec - International EPD System

3

Future of heat

Key performance indicators

1

Ensure that heating and hot water generation is **fossil fuel free**.

2

The average **carbon content of heat supplied** (gCO_2/kWh.yr) should be reported in-use.

3

Limit the peak heat loss for heating (including ventilation) to $10W/m^2$.

4

Limit the dead leg of hot water pipework to 1 litre.

Use **'Green' Euro Water Labels** for hot water outlets (e.g.: certified 6 L/min shower head – not using flow restrictors).

Summary

Client/developer (decision making)

- → Highlight the need for passive heat gain, resulting in smaller, simpler heating and hot water systems.
- → Prioritise reduced fabric heat loss so that incidental room heat gains can become primary heat source.
- → Mandate cost savings from reduced heat systems subsidise improved fabric and reduced hot water demands.
- → Require reduced occupant fuel bills, both for energy consumed and associated systems service charges.
- → Reduce room small power requirements to reflect Smart ICT fit-out and in-use feedback i.e. ~8W/m². Likewise, specify individually controlled task lighting and less blanket uniform lighting i.e. ~4.5W/m².[i]

Policymaker (strategy)

- → Set locally specific overall performance criteria and avoid being prescriptive about system type.
- → Require the same building fabric energy standards for all buildings in anticipation of potential future change of use. This reflects continued convergence between workplace and residential small power, lighting and occupancy levels.
- → Prescribe the capture of waste heat (e.g. air conditioning heat rejection) to make it available to other buildings (e.g. for difficult-to-upgrade existing stock) via heat sharing (ambient loop) networks.
- → Prepare example planning submissions for a selection of building types demonstrating net zero carbon solutions.
- → Ensure all district heating networks have roadmap to 2030 zero carbon in place.

Designer (implementation)

- → Use the LETI Heat Decision Tree at concept design stage and again at developed design stages. (See Figure 3.5).
- → Use high levels of thermal insulation and airtightness for all building types to limit the installed peak heat loss, typically to ~10W/m².
- → Limit the installed peak capacity of domestic hot water (DHW) heating plant to typically ~6W/m².
- → Use European Water Label (EWL)[ii] 'Green' rated outlets for domestic hot water and ensure a maximum 1 litre volume limit in dead-legs.
- → Select system designs that smooth out peak demands to help ease grid capacity constraints and reduce required installed capacity - harnessing thermal mass, hot water storage, electrical storage, operating diversity, etc.

i - A key heating performance gap is because SBEM's understated heat losses assume oversized unregulated room gains are responsible for satisfying much of the regulated heat demand.

ii - New EU water outlet rating system

3.0 Introduction

The way we deliver heat must dramatically change if we are to meet our net zero carbon target.

De-carbonising heat energy is a multifaceted challenge and must be considered within a wider context than has previously been the case. Other large sectors like transport will also be seeking to access the same renewable alternative energy sources, arguably with fewer alternative zero carbon options available to them.

Alternative energy carriers like hydrogen have been suggested for heat generation, but so far there is no indication that this technology could serve more than a few niche sectors. Not least is the lack of any national strategy for implementing the high predicted gas to hydrogen switchover costs[1]. On the other hand, heat for buildings can be derived from a wider range of alternative energy carriers and sources than is the case for many other energy-requiring sectors. This includes the use of waste heat, much of which is often produced within the building requiring the heat or heat available from other buildings close by.

Perhaps the greatest opportunity is simply to reduce the amount of heat actually needed to deliver the required level of amenity, be it through point-of-use demand reduction, thermal insulation, or similar measures.

SIGNPOST *Appendix 3 - Future of heat*

3.1 Contribution to zero carbon (why do it?)

Heat demand currently accounts for more than 40% of UK energy consumption by end use[2] (see Figure 3.1 opposite), with the vast majority coming from fossil fuelled natural gas.

All-electric solutions seem to be a compelling, readily available and a relatively simple means of delivering net zero carbon heat.

However, the challenge of using electricity is illustrated by how heat demand dwarfs the current electrical supply capacity. This is compounded by seasonal peaks in heat demand that exceed the total electricity supply capacity by a factor of four (see Figure 3.2 opposite). Even a complete theoretical switch to electric heat pumps with ambitious operating coefficient of performance (COP) of 4 would necessitate a doubling of the current electrical grid capacity. This is before consideration of other UK sectors also switching to electricity consumption.

To plan a way forward, it will be necessary to have an indication of how much renewable grid electricity can realistically be expected to be available for delivering heat in the future. LETI have carried out an initial study for total electricity consumption from the grid. Elsewhere, national studies[3] have also started to explore this issue.

The Energy Use (EUI) targets set out in this document for offices is no more than 55 kWh/m^2 annually of site imported renewable electricity supply, while for residential buildings it is 35 kWh/m^2. This limited renewable electricity supply would need to serve all

SIGNPOST *Chapter 1 - Operational energy*

SIGNPOST *Appendix 1 - Operational energy*

building functions, including small power, computing, lighting etc., as well as heating and cooling. The lack of alternative options for many of these other in-building operational uses of electricity means that heating requirements must inevitably be reduced by taking full advantage of all possible other point-of-use reductions, including thermal insulation, use of waste heat sources, etc.

3.2 Current challenges

The constraint on access to renewable electricity requires a fundamental rethink of how suitable heating strategies are assessed. Therefore, LETI have developed a Heat Decision Tree assessment methodology for appraising heating options (see Figure 3.5). This reflects the large number of opportunities and constraints. The following sections follow the process order outlined in the Heat Decision Tree.

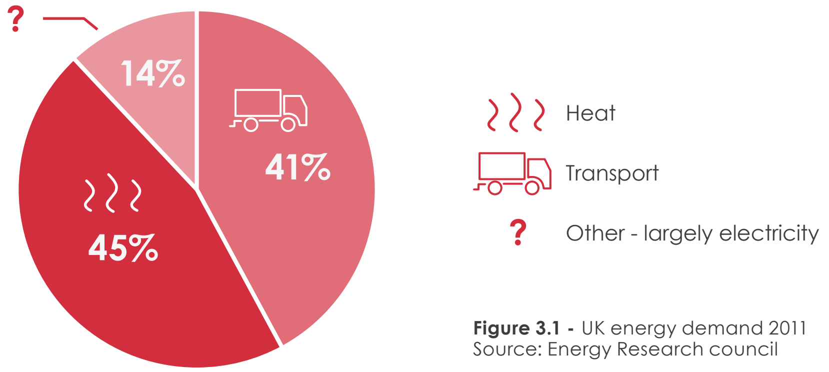


Figure 3.1 - UK energy demand 2011
Source: Energy Research council

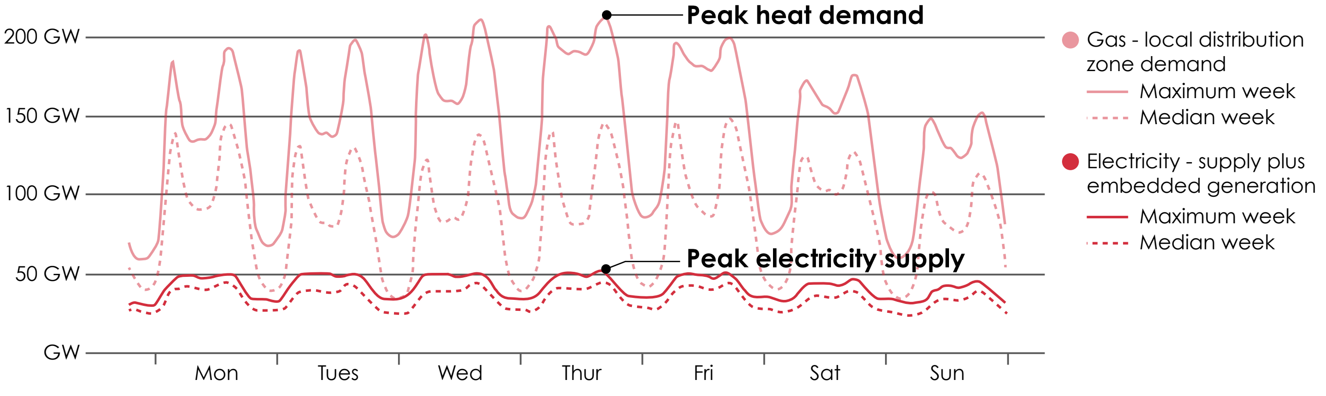


Figure 3.2 - Challenges for the decarbonisation of heat: local gas demand vs electricity supply winter 2017/2018.

Source: Energy Research Council. Britain's local gas demand and electrical system supply - median and maximum demand weeks. The week dating 22nd to 28th is the median demand week for 2017-2018 heating season. The week dating 26th February to 5th March represents the maximum demand week of the 2017-2018 heating season.

3.3 Key components/ solutions (what?)

Reduce heat demand at point of use

This is fundamental for reducing system energy demand - before considering heating system alternatives. Smaller demands open up new opportunities, not least the potential of no requirement for any heating system at all in certain circumstances.

The proposed target for the reducing space heating requirement is as a maximum installed heating plant output capacity of approximately 10 W/m^2 of floor area. This approximately equates to typical incidental room heat gains (people, appliances etc.). This means that under typical circumstances the heating system does not need to run and is only required as back-up. This same limit is proposed for all building types to allow for future change of building use without wholesale change to the base heating system. If heating plant output capacity is provided via heat pumps, this is expected to require about 6 kWh/m^2.yr of renewable electricity, either from the grid or from an on-site generated supply.

Minimising domestic hot water (DHW) demand is particularly important because of the adverse energy and carbon implication of delivering the higher temperatures DHW typically requires compared to space heating systems. All outlets should be 'Green' rated according to the new European Water Labelling (EWL) system. For example, for a shower, this equates to a maximum flow limit of 6 litres per minute (coupled with a suitable pressurised water supply system and without flow restrictors). Domestic hot water pipework should be designed to ensure there are no 'dead legs' containing more than 1 litre.

The target maximum installed output capacity of DHW heating plant is expected to be about 6 W/m^2 of floor area. This will require hot water storage with trickle recharge for most residential and other high DHW use building types. If heat pumps are used, 9 kWh/m^2.yr renewable electricity would be required, either from the grid or from an on-site generated supply.

LETI recommend to design out the need for cooling. So, just as residential developments now tend to need limited window area proportions to avoid mechanical cooling due to solar gain, the same principles should be applied to offices and other building types to likewise avoid mechanical cooling needed to removed solar gain. Typically windows are expected to be no more than 35% of facade area to be enough to maintain daylight levels. In addition, avoiding oversized windows helps reduce winter heat loss. For buildings where cooling is required for normal occupancy (i.e. excluding process loads), it is expected that those same heat gains would consequently also reduce the above annual heating demand such that the same annual energy demand target also includes the cooling input energy needs. These targets are by convention given per floor area and thus, in terms of minimising overall heat demand, it is also important to minimise the building floor area required.

Given the expected constraints on grid-delivered renewable electricity, particularly during periods of peak heat demand, building systems should be configured to harness heat at the lowest temperatures possible and hence maximise heat pumps efficiencies. While there are heat pumps that can operate at higher temperature differentials between their heat source and heat sinks, generally they all operate significantly more efficiently at lower temperature differentials and so require less grid power.

Minimise systems temperatures

In general, high temperatures in heating systems are synonymous with fossil fuel combustion as this is the most common way used in the past for heating. However, given the path to net zero carbon requires a move away from fossil fuel combustion, minimising system temperatures is a crucial step in that direction.

Lower system temperatures allow for increased system efficiencies and lower losses in conversion, storage and distribution of heat. A wide range of renewable technologies (heat pumps, solar thermal etc.). work most efficiently at relatively low temperatures. In addition, available waste heat sources are also typically at lower temperatures. Therefore, minimising system temperatures effectively opens up opportunities for integrating a wider range of low and zero carbon heating sources and can have a significant impact on the overall carbon emissions of a heating and hot water system.

A common example of how this can be achieved is by specifying underfloor heating (UFH) instead of radiators for space heating. Whereas radiators typically require a water flow minimum temperature of 45-55˚C, UFH can operate at flow temperatures as low as 25-35˚C because of its larger surface area for transferring the required heat into the room. This larger warm surface area also means comfort levels can be achieved at lower room air temperatures.

Following the same principle, room cooling (i.e. the removal of heat for potential use elsewhere) also operates more efficiently where there is a larger room surface area to deliver the required coolth. This similarly provides a larger radiant cooling effect and so achieves room comfort levels at higher air temperatures. It additionally allows higher temperature cooling distribution systems, which in turn improve heat-pump efficiencies.

Space heating peak
10 W/m²

Equiv. to 6 kWh/m².yr renewable electricity from the grid

Domestic hot water peak
6 W/m²

Equiv. to 9 kWh/m².yr renewable electricity from the grid

Plant capacity
16 W/m²

Figure 3.3 - Plant capacity calculation

Lean design

Rather than applying the generous oversizing margins buried in conventional rules of thumb when carrying out heat loading calculations, detailed load modelling will provide better predictions of energy use and help size plant requirements more accurately. Furthermore, sizing heating plant capacity using the 96th percentile approach rather than providing capacity for the full load at design conditions, reduces the heat generation equipment size and increases efficiency of the equipment in operation. Similarly, sizing and increased efficiencies are achieved by eliminating the rounding margins conventionally applied at each stage of design, plant selection and commissioning.

As the thermal performance of a building improves, it responds more slowly to drops in outdoor temperature, permitting the use of less onerous outdoor design conditions. Highly insulated buildings also mean intermittent control strategies deliver reduced benefit due to limited room temperature drops during off periods. Consequently, a strategy of trickle charge over extended operating hours can greatly reduce plant capacities and improve energy efficiencies.

Harness waste heat

After considering ways of reducing the heat demand at point of use and minimising system temperatures, the next priority should be to harness waste heat from all available sources in and around the site. Capturing heat released as a by-product of an existing process enables this otherwise wasted heat to contribute to meeting energy demands.

Air source heat pumps (ASHPs), ground source heat pumps (GSHPs) and water source heat pumps (WSHPs) are common examples of using heat from the natural environment. However, waste heat is also available from activities or processes and can be captured at different scales. At a building scale, exhaust air heat pumps are one example. Also, waste heat from cooling heat rejection and refrigeration systems can be reused as a heat source for space heating and domestic hot water systems, whilst also contributing to a reduction in the 'Urban Heat Island' (UHI) effects.

There are also opportunities to harness waste heat at infrastructure level. Sources such as London Underground ventilation[4] and industrial processes should be considered. Other sources such as water treatment and waste treatment works offer opportunities for establishing heat sharing ambient loop networks by circulating low temperature heat to nearby developments.

Join a heat sharing network

Minimising demand and system temperatures creates opportunities to establish heat sharing networks. Demand circuits with lower flow and return temperatures have a greater opportunity to harness waste heat from local sources, which can include heat rejection from buildings with cooling demands. This same heat can then be reused by buildings with a heating demand, at an improved efficiency. This is particularly useful in mixed use developments where there are different heating (and cooling) demand profiles, offering opportunities for load shifting and heat sharing. This also helps reduce 'urban heat island'(UHI) impacts caused by the heat rejection from building cooling systems.

This approach implies a step change in operating temperatures for district level schemes, away from the current norms for 4th generation district heating networks operating at 70°C flow and 40°C return or above, to 5th generation district heat sharing 'ambient loop' networks, controlled around much lower working temperatures of between 8°C and 25°C. These lower temperature networks can benefit far more readily and cost effectively from any available low temperature waste heat. See Figure 3.4 opposite.

District heat network operating economics need very careful consideration where connected to new high efficiency buildings. When heat demand is significantly reduced, eventually down to the level of 'Heat Autonomy', where most heat needs are met from incidental internal gains, there is little energy delivery cost revenue for the network operator. Network distribution losses can become larger than the quantity of delivered heat. This is likely to be reflected in significant fixed connection and services charges being the dominant energy bill component. This suggests that the effort and resource use needed for district heat networks should be focused instead on serving the difficult-to-decarbonise existing building stock, along with those building which can supply surplus waste heat.

Shortlist system solutions

Having investigated the 'opportunities' offered by the site, by harnessing building fabric enhancement, and by using all possible waste heat sources from the building and from the locality beyond the immediate site, a shortlist of possible heat systems should be tested against the constraints identified in the LETI Heat Decision Tree.

For net zero carbon, systems dependant on natural gas and other fossil fuels are expected to be unsuitable. This includes combined heat and power (CHP) and gas boilers, as well as hybrid systems that may use fossil fuels for peak demands. Where the natural

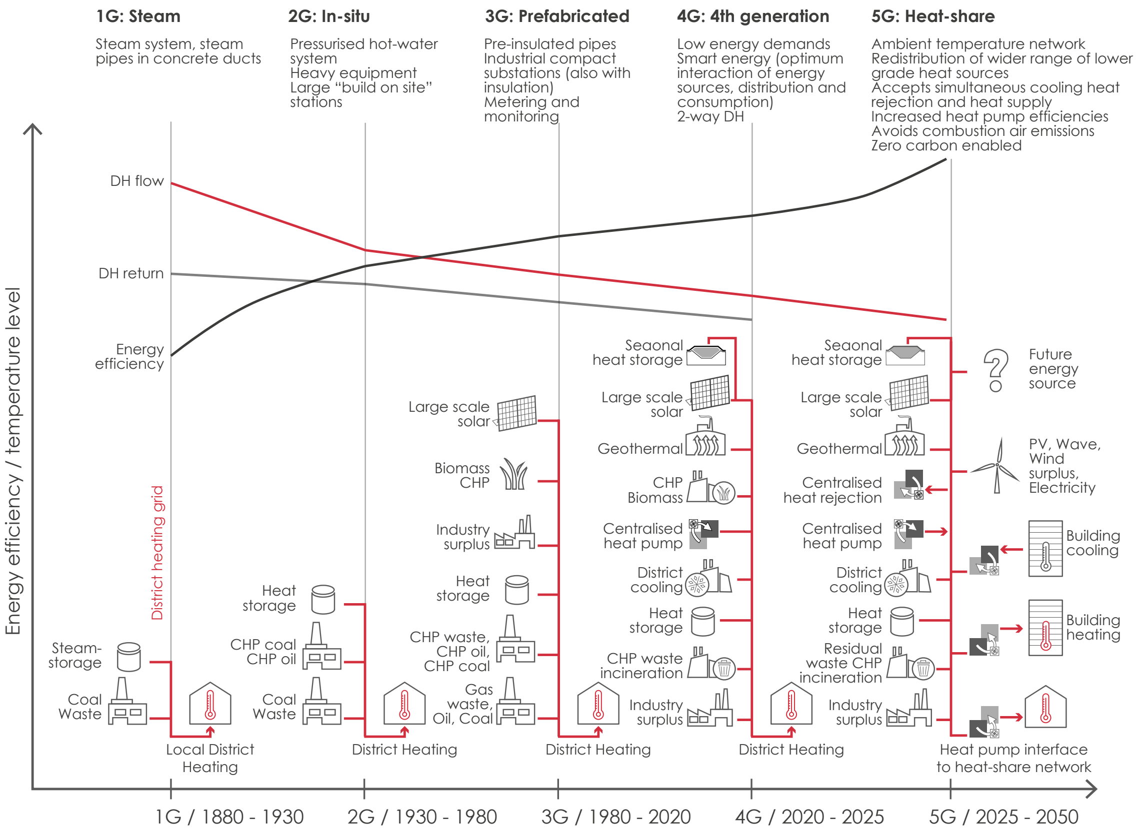


Figure 3.4 - District heating network evolution

Source : Thorsen, J. E., Lund, H., & Mathiesen, B. V. (2018). "Progression of District Heating – 1st to 4th generation". 5th generation adaptation Twinn, C.D.A. (2019)

gas network is locally converted to 100% hydrogen this can be considered but beware that much of current hydrogen production is itself carbon emissions intensive and hence not zero carbon. Connecting to district heating networks that are dependent on fossil fuels should be avoided unless there is a declared route-map to zero carbon for 2030. Energy from waste is another option, however much of the burned plastics / biomass derivatives emit CO_2 that was previously locked out of the atmosphere. Instead as part of a circular economy these materials should be recycled, reprocessed and reused. At this time the logic of how energy from waste can contribute to a zero-carbon society has not been established, and consequently at this time this is not a suitable solution.

Heat decision tree

The Heat Decision Tree below highlights the broad range of issues that the heating system selection must address, including such non-carbon issues as avoiding higher energy bills for those least able to pay. Similarly, air quality issues, particularly in urban areas, and countering the increase of future UHI, are likely to preclude combustion processes. Some of these criteria will vary from region to region and hence local planning policy will need to define locally acceptable limits with future trajectories for progressive improvements.

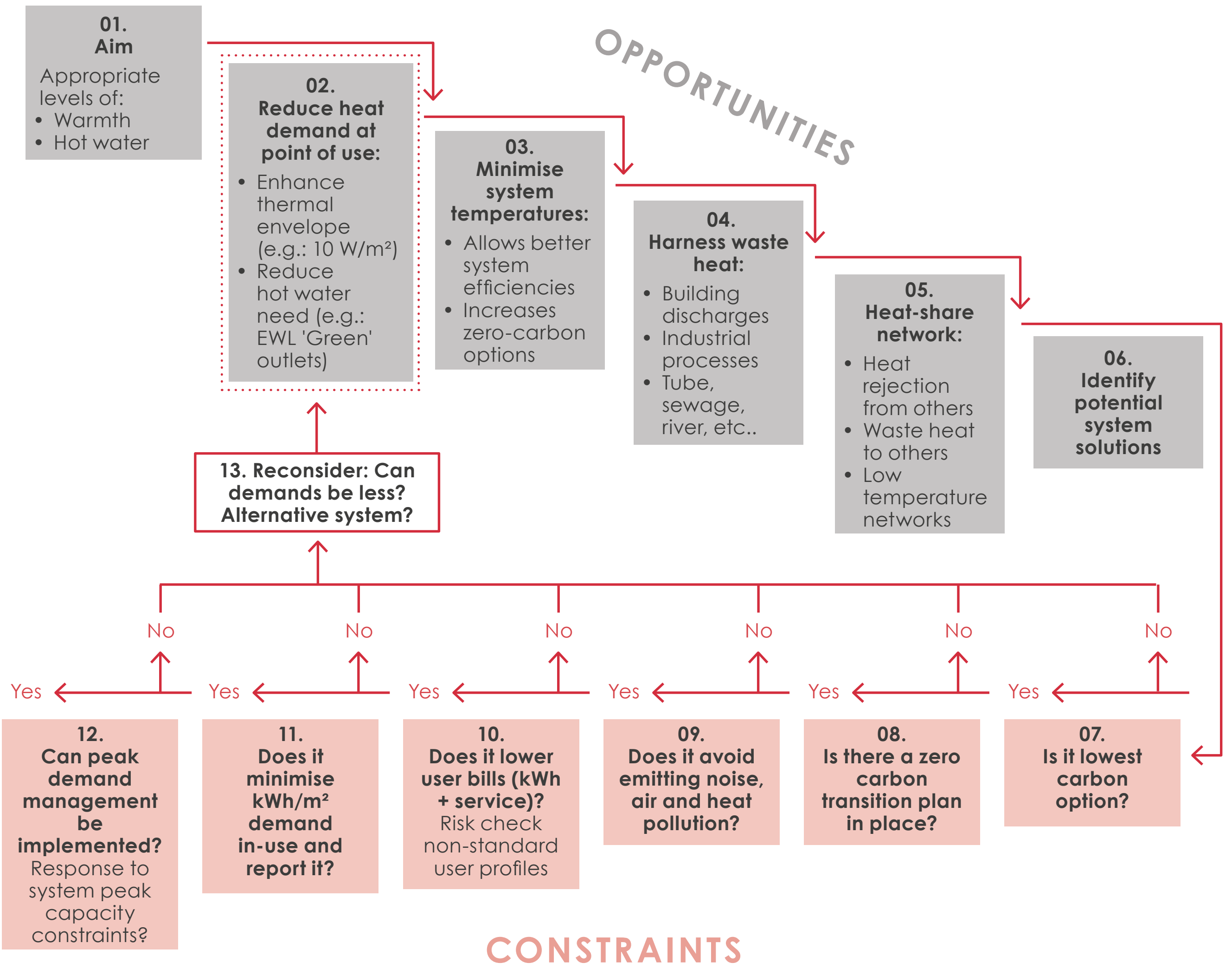


Figure 3.5 - Heat decision tree

Heat system options	Suitability for zero carbon
Gas boilers / fuel cells	Not zero carbon because of fossil fuel use. Could be zero carbon if fuelled by hydrogen created from renewables.
CHP leading with gas boiler	Not zero carbon because of fossil fuel use. Could be zero carbon if fuelled by hydrogen created from renewables.
CHP leading with gas boiler on district heating	Not zero carbon because of fossil fuel use. Could be zero carbon if fuelled by hydrogen created from renewables. Beware of relatively high distribution standing losses when serving low energy buildings.
ASHP with gas boiler peak loads on district heating	Not zero carbon because of fossil fuel use. Could be zero carbon if fuelled by hydrogen created from renewables. Beware of relatively high distribution standing losses when serving low energy buildings.
Centralised ASHP on low temperature district heat network with local WSHP upgrade for DHW	Potential for zero carbon once grid decarbonised or if powered by on-site renewables. Beware ASHPs do not operate at their most efficient at high district heating temperatures. District heat network losses reduced if operating at 'ambient' temperature of 18-25°C ideally. Low flow DHW outlets ideally to reduce high temperature demands. Beware lowest COP efficiencies and reduced capacities occur are during coldest weather.
Exhaust air heat pump (EAHP) with MVHR in each building / dwelling	Potential for zero carbon once grid decarbonised or if powered by on-site renewables. Harnesses only waste heat using 2-stage heat recovery and is dependent on enhanced thermal envelope and low flow DHW outlets.
Room WSHP units with building centralised ASHP	Potential for zero carbon once grid decarbonised or if powered by on-site renewables. Heat sharing ambient loop water network allows heat recycling within building. Can connect to district heat sharing network so heat rejected from cooling systems is redistributed to heat demand buildings.
ASHP for DHW	Potential for zero carbon once grid decarbonised or if powered by on-site renewables. Be-ware that COP efficiencies are generally quite poor for generating DHW temperatures. Future CO_2 high pressure refrigerants expected to improve COPs (see Appendix A3.2)
GSHP per building or on heat share district system	Potential for zero carbon once grid decarbonised or if powered by on-site renewables. District heat network reduced losses if operating at 18-25°C ideally. Better COPs than ASHP in winter, although poorer during summer.
DX / VRV heat pumps	Potential for zero carbon once grid decarbonised or if powered by on-site renewables. COP efficiencies are generally poor for generating DHW temperatures. Unlikely to be compatible with low global warming potential (GWP) refrigerants. Beware lowest COP efficiencies and lowest capacities during coldest weather.
Direct electric	Unlikely to be compatible with future renewable grid peak demand restrictions. Likely to increase energy bills significantly. May be suitable as back-up for zero heating buildings and for very low DHW demands.
Biomass (solid) boilers	Unlikely to be acceptable in urban areas due to fuel emissions. Harvesting and delivery also needs to be zero carbon with comprehensive forestry replenishment.

Figure 3.6 - Heat system options table

Definitions:

DHW	Domestic hot water	COP	Coefficient of Performance of heat-pump
CHP	Combined heat and power unit (gas-fired)	DX	Refrigerant piped between split units (often reverse-cycle)
ASHP	Air-source heat-pump	EAHP	Exhaust-air-source heat-pump
WSHP	Water-source heat-pump	MVHR	Mechanical ventilation heat recovery unit
		ZC	Zero carbon

3.4 Implementation mechanisms (how?)

The LETI Heating Decision Tree has been developed to provide a clear strategic approach to identify and implement future-proofed low-carbon heat amenity as part of delivering zero carbon buildings. It draws together all the major issues needing consideration before agreeing a heat strategy for a building.

The way we deliver heat amenity must dramatically change if we are to meet our net zero carbon target. De-carbonising heat is a multifaceted challenge and must be considered within a wider context than has previously been the case.

Key to addressing this for new buildings will be point-of-use heat demand reductions using significantly more efficient building fabric and hot water use, coupled with reuse of low temperature waste heat sources. There are economic payoffs to be made, including smaller heat systems, freeing money for enhanced building fabric.

Reducing building demand comes to a point where recovered waste heat can satisfy most heat needs. This suggests that the effort and resource use needed for district heat networks should be focused instead on serving the difficult-to-decarbonise existing building stock, along with those building which can supply surplus waste heat.

Early project discussions about heat are essential, not least because it involves questions about future fitout standards and building envelope, long before the normal selection of a heat system.

3.5 Case studies

19-35 Sylvan Grove, Old Kent Road

32-storey new development including 220 dwellings aiming for 69% less carbon emissions than Part L by operating using 'Heat Autonomy'.
Demand reductions include massing reduced form factor, enhanced envelope U-value of 0.12W/m^2.K, windows of 1.2W/m^2.K at 32% of façade area, airtightness of 2m^3/m^2/hr @ 50Pa test pressure and EWL 'Green' rated hot water outlets. Installed heating peak demand of 12 W/m^2 with annual heating and DHW demand of 13 kWh/m^2. Low demand to be provided by in-dwelling unit containing MVHR, exhaust air heat pump and DHW cylinder with trickle charge system. The project is zero carbon ready, based on using decarbonised grid electricity and 'Paris proofed' requiring less electricity than the anticipated 2050 allowance.

Figure 3.7 - Sylvan Grove
Copyright HTA/Joseph Homes

Tower Blocks, Enfield Council

Comprising over 400 flats in eight 12-storey towers, this retrofit project was the largest shared ground source loop array heat pump in England when completed in 2018. The array is composed of 16 shared ground loops connected to individual heat pumps installed in each residential unit via an ambient loop pipe network without the need for a central energy centre. A hot water store in each flat reduces the peak electrical demands and allows a small heat pump to deliver both hot water and space heating from the equivalent of only 40m of borehole length per dwelling.

Overall, the upgrade to the heating infrastructure resulted in a 30-50% reduction in energy bills for the residents and an estimated saving of 773 tCO_2/yr. Local combustion emissions have been eliminated for the heating system. With each flat having its own heat pump, each property is responsible for its own energy bill, and able to switch supplier.

Figure 3.8 - Sylvan Grove
Source: (https://www.thefutureeconomynetwork.co.uk/englands-most-innovative-district-ground-source-system-wins-industry-oscar)

3.6 References

1 - The CCC, *Hydrogen in a low carbon economy* [Online] Available from: https://www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy/

2 - Energy Research Council [Online]. Available from: http://www.ukerc.ac.uk/publications/local-gas-demand-vs-electricity-supply.html

3 - Dutch Green Building Council, *Paris Proof* [Online] Available from: https://dgbc.nl/themas/paris-proof

4 - Greater London Authority, London's Zero Carbon Energy Resource: Secondary Heat [Online]. Available from: https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/130220%20031250%20GLA%20Low%20Carbon%20Heat%20Study%20Report%20Phase%201%20-%20Rev01_0.pdf

4

Demand response

Key performance indicators

1. Develop a **demand response strategy**.

2. Design to r**educe peak electrical demand**.

3. **Incorporate active demand response** measures e.g. thermal storage and set point control.

4. **Influence occupant behaviour** with display and reporting of demand and usage.

Summary

Client/developer (decision making)

→ Investigate the potential for energy flexibility in developments.
→ Consider rising energy costs and the potential for an energy flexible building to take advantage of dynamic pricing in the electricity market. This can reduce occupant energy bills.
→ Be willing to invest more on control systems and metering to build 'future ready' energy systems in your developments.
→ Set a brief that allows for flexibility in meeting comfort bands. For example, in an office the temperature upper limit may be 26 degrees, but under grid constraints this could be raised to 28 degrees for short periods of time.

Policymaker (strategy)

→ Require energy flexibility assessments on all schemes.
→ Allow for carbon saved from energy flexibility to contribute towards the sustainability requirements on a scheme (Appendix 4.5 provides a method for reporting and auditing).
→ Set binding targets for minimum energy flexibility to be achieved in medium to large scale developments.
→ Develop an auditing mechanism to ensure compliance and verification.

Designer (implementation)

→ Consider the periods during the day and throughout the year that the development uses electricity, not just the total electricity consumed over the course of the year.
→ Learn about dynamic carbon factors (variation in carbon emissions from the grid at different times of the day and year) and consider them in your energy and carbon models.
→ Develop and use tools to model flexibility in the energy systems and calculate carbon reductions.
→ Specify high accuracy/resolution metering in the right places to prove when an energy-use change has occurred.

SIGNPOST *Appendix 4 - Demand response and energy storage*

4.0 Introduction

Demand side response or energy flexibility refers to the ability of a system to reduce or increase energy consumption for a period of time in response to an external driver (e.g. energy price change, grid availability).

Energy storage refers to the ability of a physical system to consume, retain and release energy as required. This allows system flexibility in response to specific energy demands.

Demand response and energy storage can both contribute to net zero carbon at the following levels:

→ **Building level –** maximising the utilisation of on-site renewables.
→ **Area level –** contributing to local grid electricity system resilience.
→ **National level –** allowing for more renewables to supply the wider electrical network.

In the future, it is predicted that energy costs will continue to rise. In order to ensure a more stable grid it is likely that time of use tariffs will become commonplace, penalising the use of energy during times of the day with high demand. Buildings that can modify their energy use in real time through the use of demand response and storage systems will be able to reduce occupants' energy bills. LETI believes that in the future it would be expected that these systems are incorporated in every new building. Figure 4.1 provides a graphical illustration of this process.

4.1 Contribution to zero carbon (why do it?)

According to the National Grid[1] demand side flexibility is a contributing factor in allowing more renewables to connect to electrical networks. Electricity networks function most consistently on the stable and predictable supply of fossil fuel, hydro and nuclear power stations. These sources of electricity can be switched on when needed to make sure the supply matches the demand on the electricity grid. Introducing generation from renewable sources, such as solar and wind, to the grid reduces the carbon intensity of grid electricity. However, renewables are naturally intermittent, and their power generation does not necessarily coincide with demand on the electrical grid.

Demand response has the following benefits:

→ When renewable electricity generation is low, demand response measures reduce the load on the grid, reducing the amount of peaking gas plant that must be switched on to meet the grid demand. This reduces the carbon emissions associated with the electricity grid.
→ Demand side flexibility reduces demand variation and grid instability.
→ Fossil fuel generation, such as peaking gas power plants used infrequently, is very expensive to run. Demand side flexibility reduces the need to keep this peaking plant in ready for use, resulting in cost savings.

The National Grid is aiming to further increase the use of renewables, increasing the need for demand side flexibility[2]. Maintaining a balanced grid is vital: it is critical that instantaneous supply matches instantaneous demand to ensure both that power cuts do not occur but also to maintain the correct voltage and frequency to ensure that electrical equipment connected to the grid operates correctly and efficiently.

The other way that the market regulates the balance is using price. Traditionally, large electrical retail companies simply give consumers a flat rate and pay the market price themselves. However, increasingly there are companies offering consumers the option to increase their exposure to market prices, and the peaks and troughs that are associated with it. Buildings that have demand response capability will be able to take advantage of flexible pricing, saving significant sums of money. Flexible pricing can lead to the price of energy becoming negative during periods of high supply and low demand. During these periods consumers are paid to consume excess grid electricity.

As well as balancing at a national scale, there is also a local grid resilience issue. The increasing uptake of electric vehicles and heating mean local grids are becoming increasingly strained. Older, smaller cables and substations will require expensive upgrades. These take time, cost money and cause a lot of disruption during the works; so being able to retain existing infrastructure without upgrades is more cost and carbon efficient.

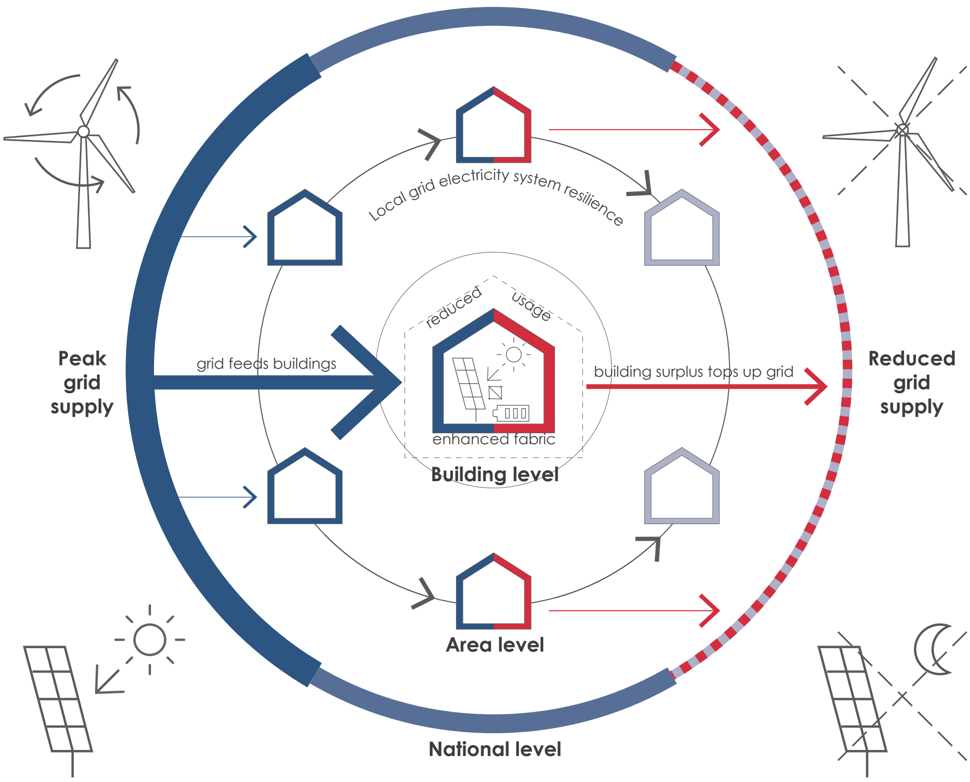


Figure 4.1 - Demand response operates at the building level and national level

4.2 Current challenges

Due to the financial rewards and increased resilience many companies are retrofitting demand response systems into their buildings. Due to a lack of regulation, a lack of representation in carbon modelling frameworks, and the fact that most of the benefits go to the operator rather than the developer; demand response systems are rarely planned in at the design stage though. Instead, they are often introduced as retrofits, which prohibit most buildings from taking full advantage of their inherent opportunities for flexibility.

Further challenges include:

→ Lack of understanding about demand response and energy flexibility in the design team and how to include this in buildings.

→ Lack of industry standard metrics to measure the 'flexibility' of buildings.

→ Lack of targets that define what good is.

→ Lack of case studies showcasing demand response measures.

4.3 Key components/ solutions (what?)

The following key components contribute to demand response and energy storage:

1. Peak reduction
2. Active demand response measures
3. Electricity generation and storage
4. Electric vehicle (EV) charging
5. Behaviour change
6. Microgrids

Peak Reduction

Passive measures and efficient systems should always take priority in the design process. They reduce demand on the grid in the first instance.

Peak reduction measures include:

→ **Heating peak reduction** – This includes: high performance fabric, a good level of airtightness, a compact form factor and thermal mass. An efficient heating system also reduces the heating peak demand.

→ **Cooling peak reduction** – Designing out the need for cooling has a large impact. If this is not possible, then the mitigation measures described in Chapter 1 can reduce the cooling annual demand and importantly the cooling peak. For example, this includes appropriate glazing ratio, external shading, thermal mass, efficient cooling system and efficient lighting.

→ **Domestic hot water peak reduction** – This includes low-demand outlets, reducing distribution heat loss and installing an efficient heating system.

SIGNPOST *Chapter 1 - Operational energy*

SIGNPOST *Chapter 3 - Future of heat*

Having a high performance building fabric will allow internal temperatures to be maintained at comfortable levels without active heating or cooling. This reduces the energy required from the grid for longer periods of time. Figure 4.2 shows the impact that a thermally efficient fabric has on reducing the peak heating load.

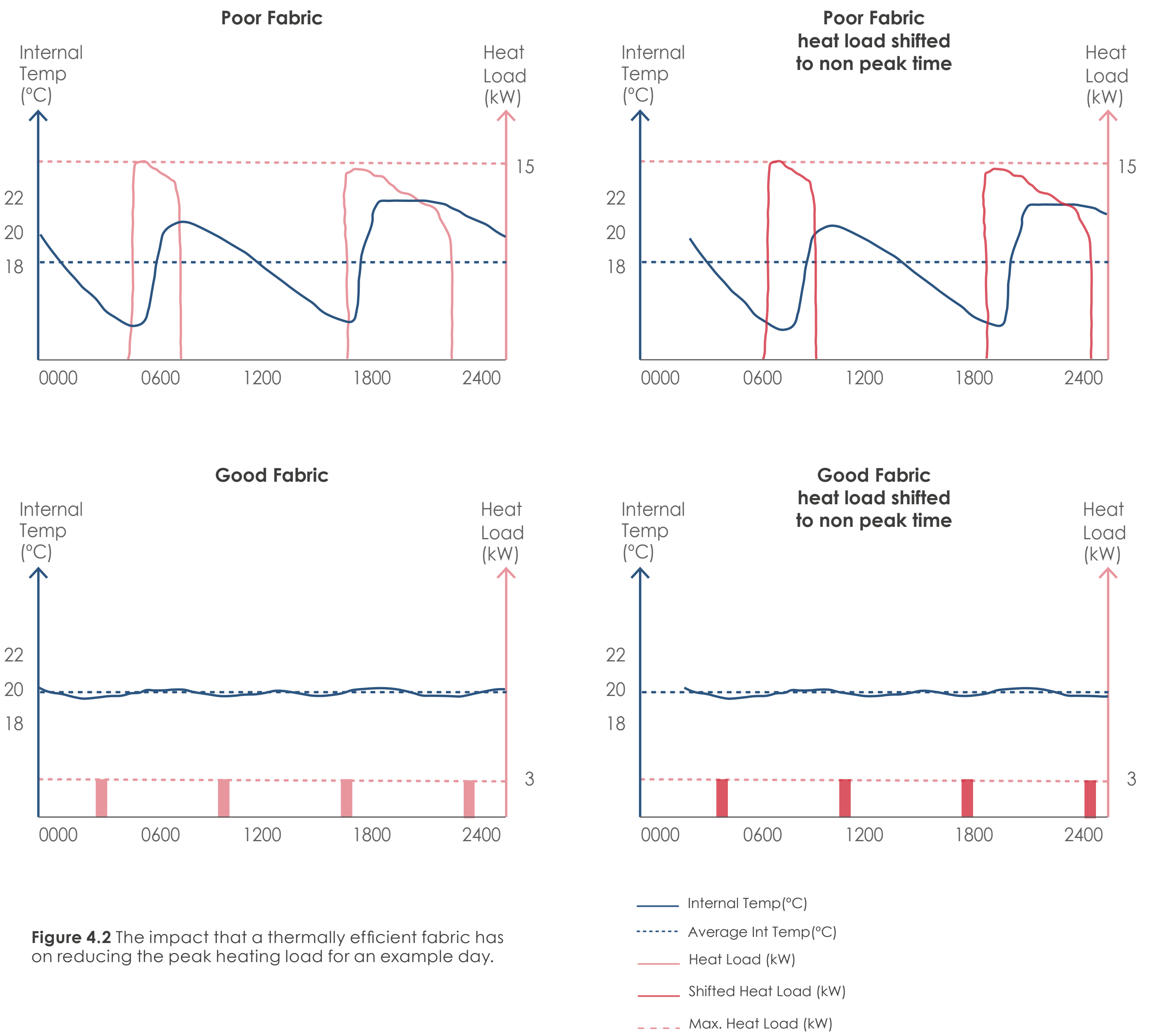


Figure 4.2 The impact that a thermally efficient fabric has on reducing the peak heating load for an example day.

Connection agreement reduction

One of the major costs of a development can often come from the connection agreement to the electricity grid District Network Operator (DNO). Using a combination of the methods listed to cap the peak energy consumption could allow a developer to negotiate a smaller energy connection agreement cost. In the future, if an asset is designed and built which is helpful to the energy network operation, and that connection would benefit the DNO, connection cost could be reduced.

Active demand response measures

Once an efficient passive design is in place, there is often an opportunity for active demand response systems to be considered. These systems would bring further carbon savings, better energy network resilience, more appropriate time of use consumption (e.g. peaks) and financial rewards. These measures reduce the electricity consumption for a certain period, i.e. during periods of grid constraints.

Current practice

Heating and cooling set point control (with increased comfort bands)

→ Can be done via the BMS, or home energy management systems such as Hive for small scale residential.
→ Metering strategy may need to account specifically for heating load.
→ This increases the comfort band, thus ramping down mechanical plant for short periods of time.
→ Heat pump systems often come with control and metering built-in, so linking with demand response systems should be straightforward.
→ Hot water systems with thermal storage often have more opportunities for active demand response.

Thermal Storage

→ Thermal storage of coolth or heat can be integrated into a communal system or individual system within a building.
→ In winter the electricity grid is more likely to be constrained at periods when homes are heated and hot water demand is high, e.g. first thing in the morning. Thermal storage disassociates when heat is produced from when this heat is required.
→ The thermal store can be charged at a period when the grid is unconstrained or low carbon, then used to provide heating and hot water during peak grid times without putting extra load on the grid.

Large building loads

→ Any given organisation may have opportunities for reducing other large loads that are part of their day to day operation.
→ Industrial refrigeration is a good example of a building load that can be varied for a short period of time without too much dependency on external factors. The thermal inertia of the system allows the cooling load to be reduced for a period without the internal temperature rising too much. This has been trialled with some major supermarkets[3].

Distributed alert system

→ Encourages residents to turn down their energy use through the use of incentives. For example, a phone app or text alert system with ‘proof of turn down’ metering analysis via the smart meter.

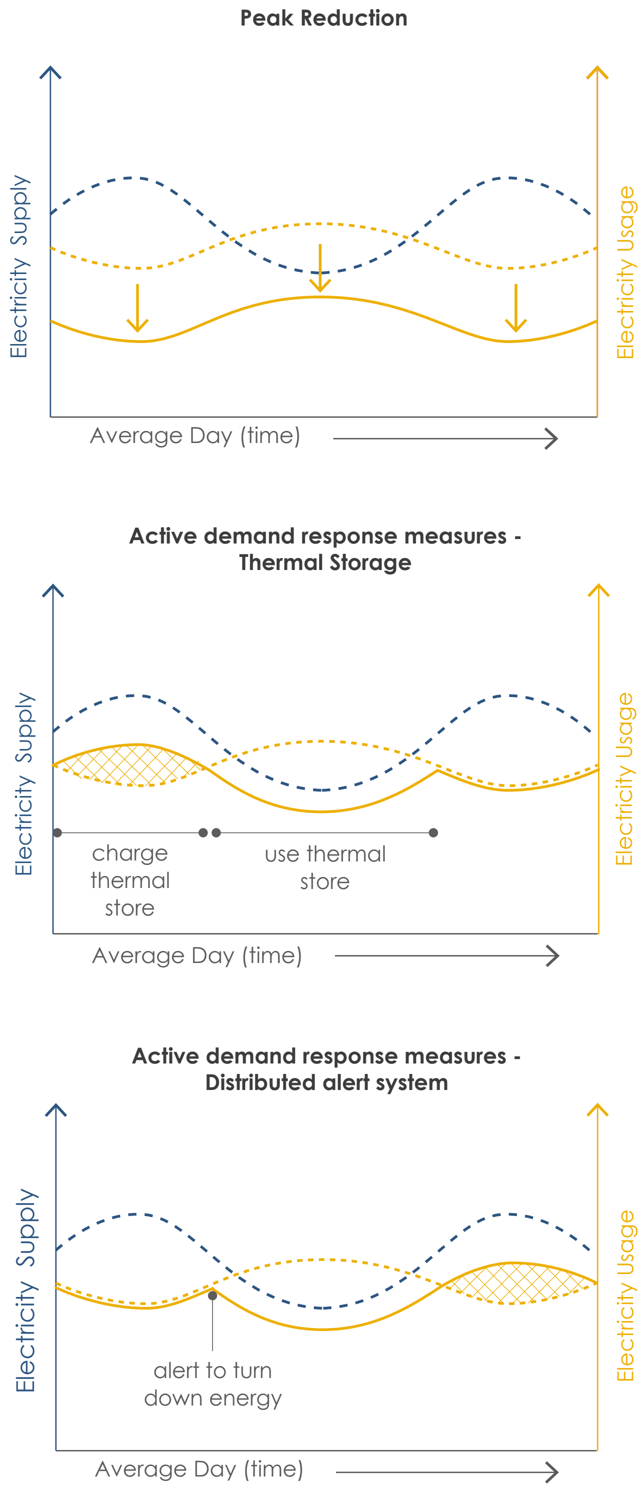
Future practice

→ Small power equipment – Has not been observed to directly participate in flexibility markets as of yet due to the high volume installation/retrofit requirements.

→ Lighting – Reduction of lighting levels in periods of grid constraints. This is currently rare due to safety concerns and potential breaching of lighting regulation, but there have been suggestions of raising and lowering the brightness of lighting levels to provide flexibility within allowed tolerances.

→ Reduction in ventilation requirements – Mechanical ventilation to ramp down to achieve minimum rates for short periods of time.

→ Voltage/power factor control
  → Once a development reaches a certain size it may be prudent to consult your local DNO to ask about voltage control or power factor response programs.
  → These work in a similar way to the standard energy consumption rate reduction seen in most energy flexibility programs, except it deals with very local grid constraint problems.



Key
- - - - - Electricity Supply
. . . . . . Electricity Usage
——— Electricty Usage with key demand responce measures

Figure 4.3 - Peak reduction and active demand response measures. Visual representations of the various demand response solutions discussed in this chapter.

Electricity generation and storage

Products that can generate electricity to feed into the grid, or power the building, reduce demand on the grid when the grid is constrained:

Battery systems
There are several different types of batteries that have relevance in different applications.

→ Lead acid – Simple car batteries, they are easy to dispose of but have poor energy density.
→ Lithium Ion – Higher energy density, used in laptops, mobile phones and now domestic battery storage systems. They have high speed energy delivery. Reconditioned used lithium batteries taken from electric vehicles when no longer meeting peak performance, are available for use in buildings.
→ Flow Batteries – Uses an electrolyte fluid and metal. The technology is increasingly finding a role at an industrial scale. The disposal is much easier than lithium batteries, and safer in operation.

Solar to hot water heat storage
Excess solar generated electricity is used to generate heat and stored as hot water. This is usually via an immersion heater in a hot water cylinder.

Electric vehicle (EV) charging

It is generally accepted that while the market penetration of EV charging is currently low it will increase as the number of electric vehicles increases. In order to ensure grid stability, it will be essential that demand response initiatives are implemented for charging loads as the number of EVs grows.

Electric vehicle turn down
This involves charging EVs only when needed and allowing the supplier to cut the charging short during peak times. The users inform the supplier when they need the EV and the minimum charge required. The electrical supplier then identifies a time for optimal charging and electricity use. A third party service provider can offer the flexibility in wholesale or ancillary services markets or to the distribution network operator. It can also be used to manage the peak demand of the building or estate, to avoid the cost of installing a higher capacity network connection.

Vehicle to Grid
This reverse charging EV technology allows the battery of the EV to be used to supply the building. The charge point supplies energy to the building during grid peak electricity periods. This is subject to having sufficient charge in the EV battery. Electricity from the battery is used behind the meter rather than using the grid supply.

Behaviour change

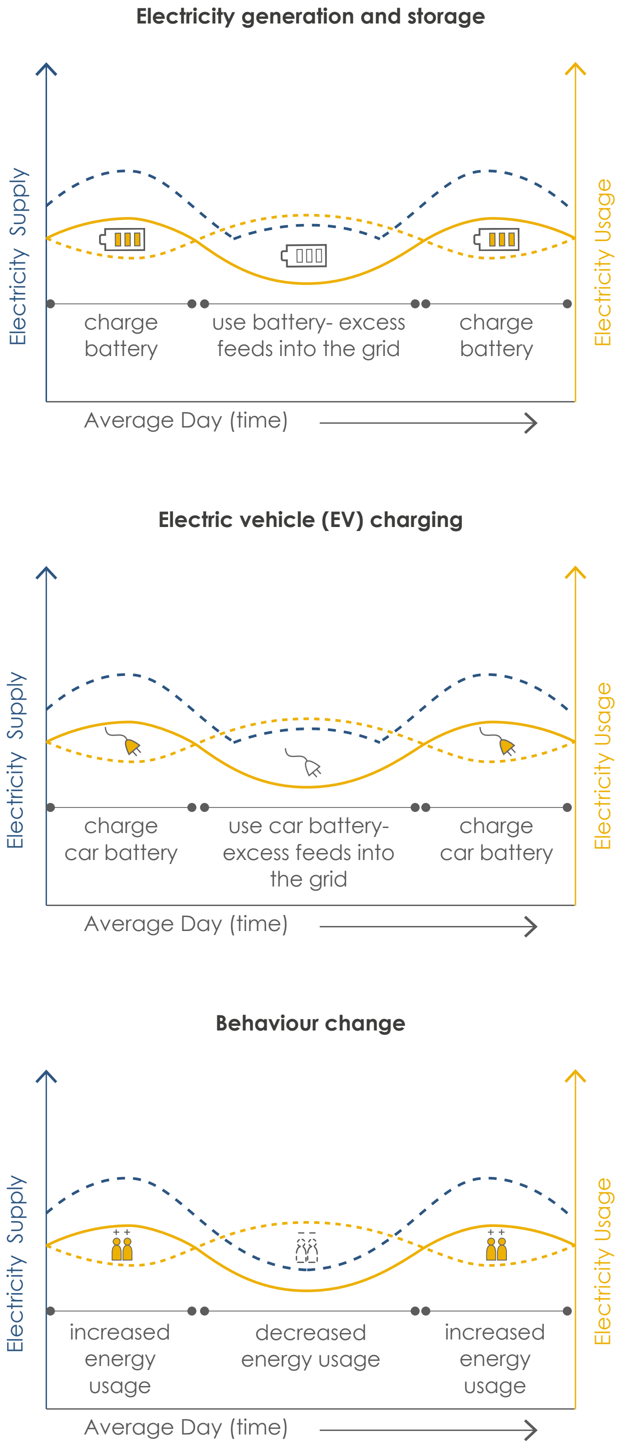
It may be worth noting that people do not generally consider the impacts of when they use electricity. Participating in educational initiatives to raise awareness and increase enthusiasm for participation in voluntary schemes to reduce peak demand would be a worthwhile endeavour.

Responsive Occupancy

If using a hot desk policy, office workers could be moved to be in the same parts of the building during periods of lower occupancy. This would allow the heating or cooling to be focussed on the occupied areas, with the unoccupied areas untreated or at a setback temperature, saving energy.

Microgrids

Being part of a small semi-isolated energy network would allow the development to operate as an 'energy island' essentially cutting itself off from National energy networks if needs arise. This is potentially quite complicated, but has a large potential to improve flexibility and reduce demand from the grid locally, see Figure 4.5.



Key
- - - - - Electricity Supply
.... Electricity Usage
——— Electricty Usage with key demand responce measures

Figure 4.4 - Generation and storage, EV charging, and behaviour change measures. Visual representations of the various demand response solutions discussed in this chapter.

4.4 Implementation mechanisms (how?)

Whatever the asset type used, the potential for breaching other agreements or regulations must be considered. LETI would advise that you define your planned approach early on in the design process so that potential clashes can be identified and avoided. LETI believe that stronger government policy in this area can help to fully realise demand response opportunities at the design stage. This will allow more buildings to have and provide the associated carbon emissions reduction and operational resilience benefits.

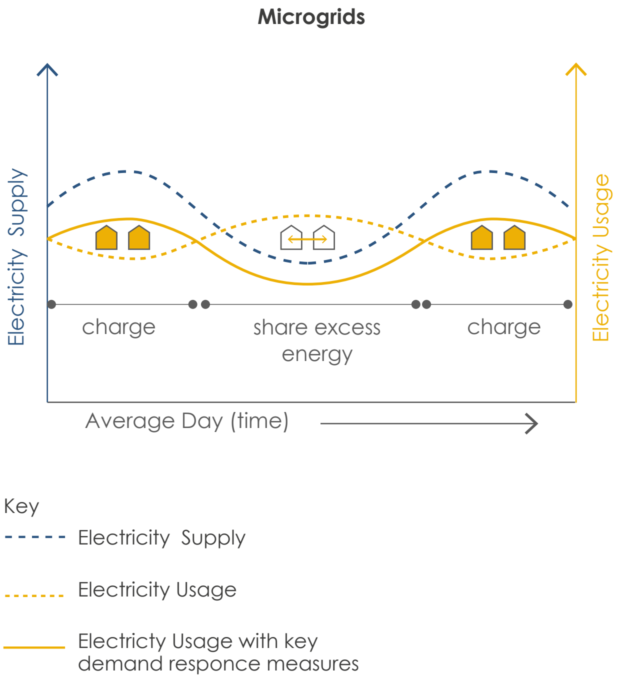


Figure 4.5 - Impact of Microgrids. The operational daily cycle of energy on a microgrid or heat network

In order to drive buildings to be more flexible in energy use and improve their ability to actively reduce their ongoing carbon emissions, LETI proposes the following policies to be included in building regulations.

→ Each building should be required to undertake an energy flexibility assessment as part of their energy statement. This assessment should record the total kW of energy available that can be controlled and how long the demand can be reduced, or energy stored for on a per building basis.

→ Following the implementation of a structured assessment process, LETI proposes that a minimum requirement should be established for all new buildings.

An example of this requirement could be, the peak load of the building should be capable of being reduced by 30% within 1 minute for at least 2 hours.

In order to implement demand response measures, an industry key performance indicator metric needs to be developed. This allows the energy flexibility of a development to be set at the design stage. The design can then be developed to meet the targets and meeting these targets can be monitored in use.

Various options for this metric are outlined below:

→ Aspect ratio – between peak energy consumption and daily average consumption.

→ How much of the year could the development use demand response systems?

→ How much of the energy use could be shifted to a different time?

→ In times of grid constraints, the development can reduce peak demands by *X* kW for *X* many hours.

→ The development can run autonomously for *X* hours.

4.5 Case studies

Dudley College's Centre for Advanced Building Technologies (Advanced II)

4,400m² of further education accommodation including seminar rooms, workshops, BIM training, offices and associated ancillary space.
Peak demands reduced by enhanced building envelope performance, modest window sizes, together with heating/cooling pipework operating at 'Ambient Loop' temperatures embedded into room-exposed ceiling and floor slab thermal mass. These measures are expected to reduce peak energy demands by some 45%. Central plant capacity requirements are likewise reduced with heating plant design capacity of less than 20W/m². Other measures include pipework configuration to ensure the variable speed pumps pressure head is no more than 50kPa. During the first year the chillers operated for fewer than 50 hours.

Figure 4.6 - Dudley College's Centre for Advanced Building Technologies (Advanced II)

4.6 References

1 - Ofgem, *Investigation into 9 August 2019 power outage* [Online] Available from: https://www.ofgem.gov.uk/publications-and-updates/investigation-9-august-2019-power-outage

2 - Wood J, *National Grid says it can go 100% renewables by 2025*, the energyst website [Online] Available from: https://theenergyst.com/national-grid-says-can-go-100-renewables-2025/

3 - Grundy A, *Tesco trials offering up fridges for frequency response*, Current Website [Online] Available from: https://www.current-news.co.uk/news/tesco-trials-offering-up-fridges-for-frequency-response

5

Data disclosure

Key performance indicators

1

Ensure total building **energy consumption** is **metered and recorded** securely and reliably.

2

Submeter renewables, heating fuel (e.g. heat pump consumption) and special uses separately.

3

Carry out an annual **Display Energy Certificate (DEC)** for non-domestic buildings and include as part of annual reporting.

4

Upload five years of data to GLA and/or CarbonBuzz online platform.

Metering strategy for commercial offices to follow BBP Better Metering Toolkit guidance.

Summary

Client/Developer (decision making)

→ Report against operational energy targets following completion.
→ Include central collection and collation of sub-metered energy data in the project brief.
→ Use a central data store and a private online data platform for collating, presenting and interrogating building or asset energy data.
→ Upload aggregated energy data to publicly available and open source data platform.
→ Consider a Display Energy Certificate (DEC) assessment annually as a reliable energy reporting framework.
→ Specify a breakdown of energy consumption by use types that are specific and relevant to the organisation, for example space heating, hot water and split between landlord and tenants. This must form the brief for the metering strategy.

Policymaker (strategy)

→ Provide an open source and public platform for sharing energy data on all buildings. Collaborate with authorities and institutions to use existing resources as a basis for developing a robust and flexible platform.
→ Post process shared energy data using annual average carbon factors to provide reliable and comparable carbon emission information for each building. Report on aggregated carbon emissions from buildings at a local level.
→ Mandate operational energy ratings and energy disclosure for new buildings for a period of at least five years.
→ Enable and encourage continued reporting of energy consumption data for existing buildings, for example through automated reporting.
→ Review Display Energy Certificate benchmarks and guidance.

Designer (implementation)

→ Identify the outcomes that will be monitored and ensure the metering strategy can achieve this.
→ Specify, design, commission and document sub metering to suit the size and use of the building, to allow identification and diagnosis of problems, and to give a breakdown of consumption by use type.
→ Use a dedicated data store to save energy consumption information, do not rely on the BMS.
→ Prepare a building Log Book at handover.

5.0 Introduction

It seems obvious, but reducing the actual carbon emissions arising from a building's construction and operation is what matters. This is what will reduce the construction sector's impact on our climate. To measure and report actual carbon emissions and drive reduction, we need to measure and report energy consumption at a far larger scale than currently achieved, and to make the process far more simple and transparent.

More than this, we know there is still a performance gap between the design estimates and operational energy and carbon emissions of buildings. To make buildings better, we need to create or improve the feedback loops between buildings in operation and design.

There has been a lot of good work in this area, but it is complex and previous efforts have stalled. A fresh, invigorated and collaborative industry-wide push is needed to build on what has come before, and help building designers and clients to understand the energy use and emissions of buildings. This requires two main actions:

Improving the scale, quality, consistency and visibility of energy data reported by building owners and designers.

Improving access to building energy data and insights through reporting platforms.

This section focuses on the first action and gives best practice guidance for setting up energy data collection from a bottom up, building by building perspective.

We acknowledge that monitoring building operational energy consumption is one small part of post occupancy evaluation and improving buildings, but it is an urgent and tangible one. Collecting data on other building metrics such as occupant satisfaction, embodied carbon, water consumption etc.. should be added to any successful mechanism and platform in the future.

5.1 Contribution to zero carbon (why do it?)

The absence of reliable, independent, trusted data on building performance has led to a situation where the performance of, and emissions from, buildings is broadly unknown.

Measuring and reporting real energy consumption means the actual carbon emissions arising from buildings can be calculated and verified during operation, and the effectiveness of the other measures described in this guidance evaluated. With real energy data we can:

→ assess progress
→ make building energy consumption visible
→ improve benchmarking and targets for new buildings
→ demonstrate what is possible
→ share successful interventions
→ speed up change in the sector.

5.2 Current Challenges

The construction industry is unanimous in agreement that more feedback and more data would improve building design and reduce carbon emissions, and has been for some time. However, attempts to galvanise this into action, like the collaborative CarbonBuzz[1] website, have not yet evolved into the tools the industry needs. The many and disparate data sets that do exist, built up with great investment and intent, often do not share data or subscribe to open data standards. This prevents this valuable information from contributing to improving performance or allowing designers to learn what does or does not work. Schemes like the Better Building Partnership (BBP), Real Estate Environmental Benchmark, CDP, GRESB and BRE's collected data on BREEAM, could all play a massive part in getting to zero carbon if they publicised and shared their data.

Main challenges for data disclosure from past industry experience

A..C	**Data is often very poor quality**	This can be due to anything from mistakes in data entry, meter reliability, metering design issues, and lack of commissioning or setup, to incorrect or out-of-date conversion factors, confused time periods, undefined responsibility and selective reporting.
	Data often lacks context	Anonymous or poor background information can make data useless for analysis. Common missing information types are location or setting, basic occupancy information, end use, presence of any unusual energy intensive activities, and even simple building information like floor area.
123	**Metering and collection is not joined up**	There is often no central storage or repository for data, or meters simply are not connected and metering information is lost. Typically there are meters installed, but what is metered is often poorly configured, not properly commissioned and how the data is stored is not resolved.
	Buildings are complex	There are a myriad of building types. This can often lead to confused reporting, for example not knowing whether energy is reported for a single building or the whole site when one energy supply covers multiple buildings, or separating landlord and tenant energy use in a multi-use building. Sub-metering requirements in client briefs or environmental standards mean there is often a very high level of data resolution, however collating this information into useful and consistent reporting can be extremely difficult.
£££	**It is an additional cost**	Monitoring and post processing data can be expensive or perceived as expensive. Often proposals are overly complex and focus on what can be metered rather than what information is needed and what should be reported. For one-off building clients or developers there is little incentive, or perceived benefit of monitoring and it is seen as optional.
	Privacy or commercial interest concerns prevent sharing	A tension can exist between transparency and privacy or commercial interests. There is an expectation that the data collected about a building is worth something, and a fear that it could expose valuable information about a client or organisation. For example landlords could be wary of being penalised for excessive energy use by tenants. If performance is poor, data disclosure at a building level is perceived to create a risk to a business (a threat to yield or asset value).

Figure 5.1 - Challenges for data disclosure

5.3 Key components/ solutions (what?)

LETI proposes a framework for collecting and reporting data which is simple, appropriate to the scale of the building, and prioritises reporting basic information well, rather than complex information badly.

Data disclosure is about sharing basic but useful metered data and context. Consistency is key to making useful comparisons. Building owners and designers may decide to go into more detail in order to optimise or diagnose specific issues with their building, however the proposals here should be seen as the minimum requirement and the priority for any data collection infrastructure.

The purpose of data disclosure is **transparency** and **feedback**. However, once the principle of disclosure is established it would allow mandatory operational energy standards to be introduced.

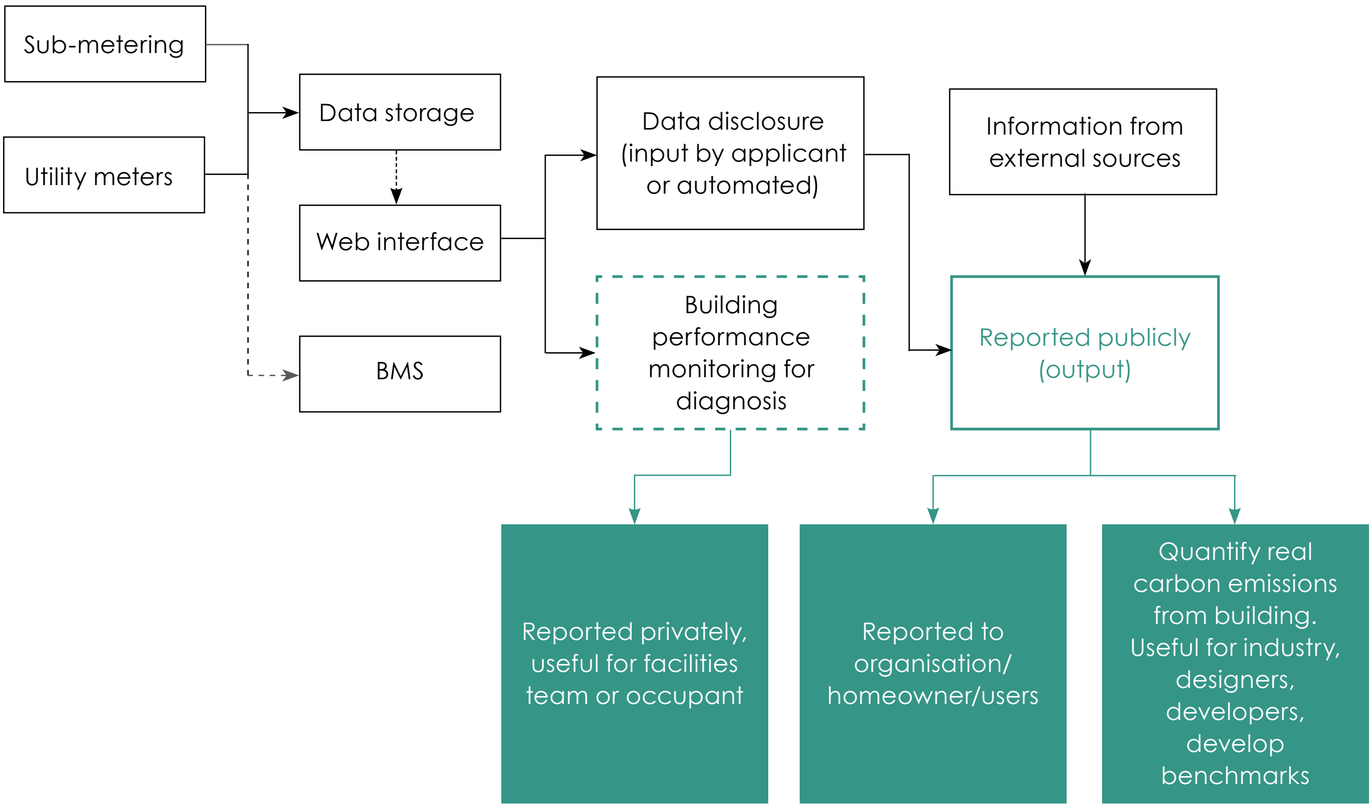


Figure 5.2 - The flow of information from building metering to reporting. The difference between data for disclosure, data that is publicly reported, and data for building diagnosis is shown.

How data is reported

The developer should disclose energy data and key building context information on a publicly available and open source data platform for a minimum of five years. Where consumption data could be sensitive, buildings/dwelling are aggregated or averaged rather than anonymised. The data would be in the public domain and should use an open data license such as the Open Government Licence or Creative Commons 4.0[2].

The responsibility for reporting should lie with the building developer. This could be passed on to third parties who would be responsible for reporting back to the authority and the building/dwelling owner. It is acknowledged that there are very few policy mechanisms to penalise developers who do not report. Nevertheless, softer incentives, consumer interest and input from building professionals could create a culture of disclosure that is a vast improvement over the current situation. Incentives might include public lists of developers who have not submitted within 14 months, and publicity for schemes that have reported data.

At present a simplified reporting structure based on manual input has been described as a way to implement data disclosure quickly. This should not rule out development of more automated reporting in the future. Working towards automated energy reporting of individual buildings or small geographical areas would be a step change in feedback. However current efforts are limited due to potential data security risk, and the lack of context for meter readings. Metering and energy companies do not collect information about the building.

In the short term the recommended platform for data disclosure is CarbonBuzz[1] to allow immediate action. Users could consider uploading to the AECB Low Energy Building Database[3] as well. However, new platforms should be adopted as they are developed. In particular this includes the 'Be Seen' reporting framework for the London Building Stock Model (LBSM) from The Greater London Authority (GLA), and new platforms from the RIBA and CIBSE. These new platforms should ensure that it is possible to share building information between databases to avoid duplicating input. The LBSM will have the capacity to capture energy performance targets (e.g. predicted DEC ratings for non-residential buildings) for major new developments in London and to show if these are achieved when operational data becomes available, fulfilling the 'Be Seen' element in the new (2020) London Plan.

It is hoped that by creating a culture of robust data collection and disclosure, and increasing the amount of building information available, there will be more interest and a larger incentive to improve the tools for sharing and interrogating that data. If we collect it, then they will want to use it.

What data should be reported?

Data should be reported for the whole building, but complex buildings can separate reporting by use category, for example to differentiate between residential and commercial, and landlord and tenant. Annual energy consumption by fuel type and annual energy generation is required, along with some contextual information about the building. The data should be reported for a minimum of five years. The reporting platform is likely to allow further voluntary input, so this guidance gives the minimum required for robust net zero carbon reporting.

All the information listed should be brought together and uploaded, however not all this data would be made public.

The developer would have final responsibility for energy disclosure, but they could identify a person responsible for reporting to pass on the management of this. This could be a continuing lightweight appointment for part of the design team, a specialist service, or taken on by the building owner or energy manager.

Information to be reported

Property information	→ Address including postcode
	→ Completion date of building
	→ Building regulations Part L version used
	→ Number of dwellings
	→ Total floor area OR Total useable floor area and the definition used for calculation
	→ Building description and photo
	→ For Display Energy Certificates (DEC)s:
	    → Date of assessment OR Issue date
	    → Certificate reference number

Building categorisation	→ DEC Category(s) OR Residential use category(s) → Gross internal floor area for each use (from DEC Full Technical Table) → Single defined building OR Number of buildings
Energy consumption	→ Provided over a bespoke date range and normalised to year by platform → Metered electricity consumption (kWh) → Metered gas consumption** (kWh) → Other fuel consumption** (kWh) → Data source quality
Heat consumption	→ Only required for projects on district heating, optional for others → Metered heat consumption for building (kWh) → Heat network provider* (Carbon factor will be supplied by the heat network provider)
Energy generation	→ Provided over a bespoke date range and normalised to year by platform, split between PV and other → Metered electricity generation (kWh)
Carbon offset	→ Annual CO_2 emissions that are offset (displaced emissions)*

*Not currently possible to input to CarbonBuzz, but should be recorded in notes.
**Other fuel and heat consumption are combined into one output on DECs

Figure 5.3 - Suggested information to be reported for data disclosure

The platform calculates carbon emissions and other reported metrics (e.g. total kWh/m^2 consumption). This means that the carbon factors and calculation method are consistent. CarbonBuzz uses out-of-date carbon factors and so cannot currently be used to report, however this can be updated retrospectively and would be a key part of any new platform.

For non-domestic buildings an annual Display Energy Certificate is sufficient to satisfy the majority of inputs. The assessment is carried out by a competent person and has the advantage of quality assurance on data input. The Full Technical Table should be requested from the assessor to assist with input.

A new data platform

CarbonBuzz is now an old platform and has more or less fallen out of use (only two projects were uploaded in 2018). It is cited here as the best operational platform for collecting building data available. However, it is dated, complex and presents a further barrier to uploading energy performance data. Improvements to the CarbonBuzz platform, or a new platform are needed. The RIBA and CIBSE are considering delivering new data platforms in 2020. The GLA and UCL are working on a London Building Stock Model (LBSM) that would allow reporting of energy consumption. LETI fully support these initiatives and hope that it can be part of a collaborative industry and Government effort to provide national building statistics.

LETI recommends that any new platform should:

→ Migrate the existing data from CarbonBuzz and allow other databases to import or export information, for example from the AECB Low Energy Building Database.
→ Make raw source data available to the public for research through open source licensing.
→ Simplify the reported information to the least amount possible, see the LETI GLA energy disclosure flow diagram in Appendix 5.1.
→ Ensure data upload and access can be automated through other platforms by including a web accessible Application Programming Interface (API).
→ Check information as it is inputted and provide feedback to catch mistakes. For example, warning messages where data is very different to that submitted previously for the same building or for other similar buildings in the dataset.
→ Report each year of carbon emissions with the average annual grid carbon factor to give estimated carbon emissions.
→ Provide simple email messaging to remind users about reporting due dates.
→ Encourage and allow voluntary upload of energy consumption of existing buildings.
→ Encourage voluntary sharing of further detail, such as: breakdown of consumption by end-use, by landlord areas/ tenants and any unusual energy intensive activities.

SIGNPOST *Appendix 5 - Data disclosure*

What data is made public?

Future platforms should publish open data for transparency, analysis and research purposes. The platform should post process and give options for aggregation so that the exact building and user could be hidden. However, the user should be able to, and be encouraged to, publish all information voluntarily if they wished. The energy data is aggregated to annual consumption and would be published at least two months after the reporting data to reduce the sensitivity. Public reporting could use consumer friendly metrics, such as star or A-G ratings. However the technical details are necessary for designers and building professionals to diagnose actions. For housing, aggregation of data across dwellings on the same street could be used.

How data should be collected?

At its most basic, data collection could be manual input from utility meter readings reporting consumption in kWh for a given period. However, for most buildings some level of automated metering and data logging is likely to be useful. How this is implemented is crucial to the reliability of readings.

The following information should be published by the platform

ABC	**Property information**	→ Postcode or part of the postcode (e.g. first four digits) → Completion date of building(s) → Building regulations Part L version used → Total floor area OR Total useable floor area and the definition used for calculation → Number of buildings → Number of dwellings (may be aggregated between buildings)
	Building categorisation	→ DEC Category(s) OR Residential use category(s) → Gross internal floor area for each category → Data source quality
CO_2	**Carbon emissions**	→ Total annual CO_2e emissions from building ($kgCO_2e/m^2$)* → Total net CO_2e emissions from building ($kgCO_2e/m^2$)* → Total annual CO_2e emissions ($kgCO_2e$)*
123	**Energy**	→ For each year reported, normalised to whole year → Total annual energy consumption kWh/m^2 → Total annual primary energy $kWhe/m^2$ → Estimated annual energy cost per residential unit (£p.a.) → Metered electricity consumption (kWh) → Metered gas consumption** (kWh) → Other fuel consumption** (kWh) → Metered electricity generation (kWh)

*See appendix 5 for proposed reporting structure for details
**Other fuel and heat consumption are combined into one output on DECs

Figure 5.4 - Suggested information to be published on a reporting platform

SIGNPOST *Appendix 5 - Data Disclosure*

Data should be quality assured prior to submission and the nature of the assurance process should be reported alongside energy disclosure. For small schemes this might include self-verification against utility bills, but for larger buildings should include third party verification or independent certification.

Display Energy Certificates (DEC) are the recommended approach for collating energy data for non-domestic buildings. In addition to the DEC there should be separate optional reporting for energy use that is the responsibility of landlords (basebuild ratings), tenants (tenant ratings) and special areas such as data centres. The DEC methodology and reporting should be reviewed and changes to the reporting scale considered to allow future continuous improvement.

Where a building is occupied by several tenants, a requirement to make energy data available for aggregated reporting should form part of the tenancy lease agreement.

Annual energy data is likely to be collected as a small part of more complex energy sub-metering. The design of the system must allow for annual data collection, for example by including sufficient storage, and cumulative readings. Data should be collated at least once per year. Annual energy consumption is a useful metric to report to the building owner, organisation, tenants, board or shareholders etc..

In time, providers of energy monitoring services should be able to report directly to the public energy disclosure platform via an API. For example smart meter providers could provide aggregated statistics for small geographical areas. This would require a connection between meter readings and building context to be established.

Zero carbon trajectory

Building designers and developers should start compiling energy monitoring data and reporting information straight away. There is already a huge data gap in reporting actual energy use from buildings, we cannot delay further.

All new projects should include a metering strategy and central repository to ensure future public energy disclosure is simple to implement. Projects can upload complete information to CarbonBuzz as a stop gap before an improved publicly accessible platform is developed. Existing buildings can also focus on recording and reporting annual energy consumption data in line with these recommendations.

By 2022 all new buildings should be reporting energy data publicly. This reporting will be useful in ensuring the aims of other sections have been addressed, for example working to close the performance gap, quantifying actual operational carbon emissions, providing consumers with information to drive retrofit, and understanding further benefits such as reducing fuel poverty.

Summary of recommendations for each archetype

Archetype		Good practice	Best practice
Small scale residential		→ Use a smart meter for continuous monitoring. → Include a power socket near the consumer unit and utility meters to power data logging equipment. → Provide a visual energy display device to raise awareness and make users responsible for their energy consumption. → Renewables are sub-metered for generation. → Special uses such as electric vehicle charging is sub-metered.	→ Separate standalone monitor and data logger alongside smart meter, or process to collect data. → Heat supply is sub-metered (e.g. heat pump electrical consumption). → Internal temperature monitoring.
	123	→ Annual building energy consumption and generation is collected by owner reporting, can be aggregated and averaged by post code for anonymity.	→ Upload data to publicly accessible database for five years.
Medium scale residential		→ Additional meter on the main resident's supply (or residents meter readings need to be collected and collated individually). → Renewables are sub-metered for generation. → Special uses such as electric vehicle charging is sub-metered. → If there is a heat network use individual heat meters per dwelling. → Provide a visual energy display device to raise awareness and make users responsible for their energy consumption.	→ Meter and report landlord areas separately. → Sub-meter heating energy by dwelling. → If there are commercial areas meter and report these separately. → Ensure OFGEM compliant meters.
	123	→ Upload data to publicly accessible platform for five years.	→ Annual energy consumption per dwelling reported (without address). → Report heating energy consumption.
Large scale residential		→ Additional meter on the main resident's supply per building (or residents meter readings need to be collected and collated individually). → Renewables are sub-metered for generation per building. → Special uses such as electric vehicle charging is sub-metered. → If there is a heat network use individual heat meters per dwelling. → Provide a visual energy display device to raise awareness and make users responsible for their energy consumption.	→ Meter and report landlord areas separately. → Sub-meter heating energy. → If there are commercial areas meter and report these separately. → Ensure meters are OFGEM compliant.
	123	→ Upload data to publicly accessible platform for five years.	→ Annual energy consumption per dwelling reported (without address). → Report heating energy consumption.

		Good practice	Best practice
Commercial office		→ Metering strategy following BBP Better Metering Toolkit guidance. This includes: → Using a central repository for data that has a minimum of 18 months data storage. → Clearly labelled meters, good documentation and schematics - serial number and usage. → Sub-meter tenant and landlord area energy use separately. → Sub-meter renewable energy generation.	→ Ensure meters can provide consumption by end use with minimum breakdown: → Heating and cooling → Ventilation → Domestic hot water → Lighting → Small power → Servers → Pumping → Lifts + escalators → Catering → Special uses e.g. server rooms
	123	→ Carry out an annual DEC. → Report energy consumption by building category from DEC technical table. For multi-let commercial offices produce annual landlord energy (base building) rating and tenant ratings as well as or instead of a whole building DEC. → Upload data to publicly accessible platform for five years.	→ Report consumption by end use per building. → Report special uses separately. → Require reporting of base building and whole building "base load" (out of hours) electricity demand (W/m^2), and proportion (%) and amount (kWh/m^2.yr) of whole building annual electricity use that occurs out of hours (outside core and shoulder hours of use).
School		→ Metering strategy following BBP Better Metering Toolkit guidance. This includes: → Using a central repository for data that has a minimum of 18 months data storage. → Recording at a minimum of half hourly time steps. → Clearly labelled meters - serial number and usage. → Good documentation – schematics with meters and end use. → Maintenance and use strategy. → Sub-meter renewable energy generation.	→ Ensure meters can provide consumption by end use with minimum breakdown. → Heating and cooling → Ventilation → Domestic hot water → Lighting → Small power → Servers → Pumping → Lifts → Catering → Special areas and uses (e.g. labs and swimming pools)
	123	→ Carry out an annual DEC. → Upload data to publicly accessible platform for five years. Include information about building (do not anonymise).	→ Report consumption by end use per building. → Report special uses separately.

Key

Metering

123 Disclosure

Figure 5.5 - Summary of recommendations by archetype

5.4 Implementation mechanisms (how?)

To enable a reporting system to work, a robust reporting platform is required that provides a simple and reliable method for organisations to provide and extract useful data. LETI has included recommendations on what this platform should include.

To kick start energy disclosure to this platform the Greater London Authority (GLA) are planning to mandate energy disclosure for major planning applications (>10 dwellings, >1000m^2). This should be extended to all non-domestic buildings as a further step. It is also crucial that existing buildings that wish to use the system are encouraged and incentivised to do so.

Once a significant amount of information is publicly available and usable, building owners and occupiers may begin to see the value in reporting and using this data to inform their business decisions. Levels of awareness could be raised and maintained through public recognition of reporting organisations, validation within industry benchmarking services such as Carbon Disclosure Project (CDP), Global Real Estate Sustainability Benchmark (GRESB), Chartered Institution of Building Services Engineers (CIBSE), and even through the use reporting as a consideration within the property policies of public sector bodies and other major occupiers.

5.5 Case Studies

Boston energy map

The Boston building energy reporting and disclosure ordinance[4] requires Boston's large and medium sized buildings to report their annual energy and water use. It further requires buildings to complete a major energy savings action or energy assessment every five years. The Boston energy map[5] gives building level greenhouse gas emissions along with information about the building and its user.

Energence automated energy monitoring platform

Since 2013 Ealing Council have required all applicants or developers submitting major development proposals to planning to undertake monitoring post-construction to demonstrate compliance with the energy policies of the Local Plan. Ealing Council worked with Energence to create an Automated Energy Monitoring Platform (AEMP) so that developers can upload information that is checked with minimum input. They can pay up front subscription costs to the scheme through their Section 106 payments, meaning no further input is required. The data does not appear to be available publicly and is not an open source. It is not known how successful this scheme has been.

Australian NABERS scheme

The National Australian Built Environment Rating System (NABERS) is an operational reporting benchmark which has significantly disrupted the market for commercial buildings by creating a demand for buildings with lower energy consumption. It has demonstrated continuous reduction in operational energy consumption since it's introduction.

A NABERS type scheme is being introduced to the UK by the BBP, see Design for Performance[6].

NABERS publicly disclose operational energy performance of buildings using the scheme. 'Nabers by numbers[7]' is a useful example showing how the open source data has been used to create visualisations and call out individual building owners on energy consumption.

TFL Palestra building

Transport for London's Palestra building achieved an initial Display Energy Certificate rating of G(182) when first commissioned in 2010. Through building performance evaluation and careful monitoring the rating was reduced to a DEC of D(93) in 2019. This demonstrates how high-level reporting of building energy consumption can incentivise organisational change and deliver real carbon emission savings.

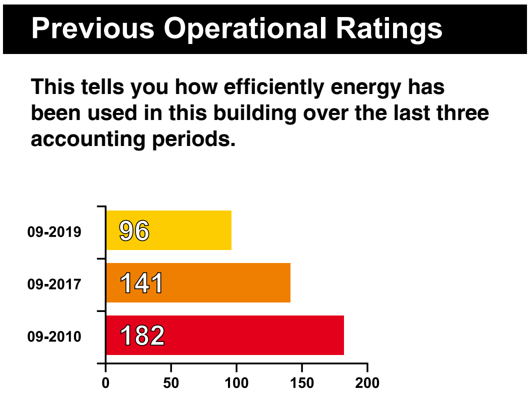


Figure 5.6 – Extract from the DEC certificate for Palestra building in 2019 showing three previous energy ratings back to 2010.

5.6 References

1- *CarbonBuzz [Online]. Available from: http://www.carbonbuzz.org/*

2 - *Creative Commons [Online]. Available from:* https://creativecommons.org/licenses/by/4.0/

3 - *AECB Low Energy Buildings Database [Online]. Available from: http://www.lowenergybuildings.org.uk/*

4 - City of Boston, *Building Energy Reporting and Disclosure Ordinance* [Online]. Available from: https://www.boston.gov/departments/environment/building-energy-reporting-and-disclosure-ordinance

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7 - NABERS, *NABERS by Numbers* [Online]. Available from: https://public.tableau.com/profile/richardstokes88#!/vizhome/NABERSbyNumbersv2/NABERSbyNumbers

A

Appendix

A0.1: Net zero operational carbon

Net Zero Operational Carbon

Ten key requirements for new buildings

By 2030 all new buildings must operate at net zero to meet our climate change targets. This means that by 2025 all new buildings will need to be designed to meet these targets. This page sets out the approach to operational carbon that will be necessary to deliver zero carbon buildings. For more information about any of these requirements and how to meet them, please refer to the: UKGBC - Net Zero Carbon Buildings Framework; BBP - Design for Performance initiative; RIBA - 2030 Climate Challenge; GHA - Net Zero Housing Project Map; CIBSE - Climate Action Plan; and, LETI - Climate Emergency Design Guide.

Low energy use

1. Total Energy Use Intensity (EUI) - Energy use measured at the meter should be equal to or less than:
   - **35 kWh/m^2/yr** (GIA) for residential[1]

   For non-domestic buildings a minimum DEC B (40) rating should be achieved and/or an EUI equal or less than:
   - **65 kWh/m^2/yr** (GIA) for schools[1]
   - **70 kWh/m^2/yr** (NLA) or **55 kWh/m^2/yr** (GIA) for commercial offices[1,2]

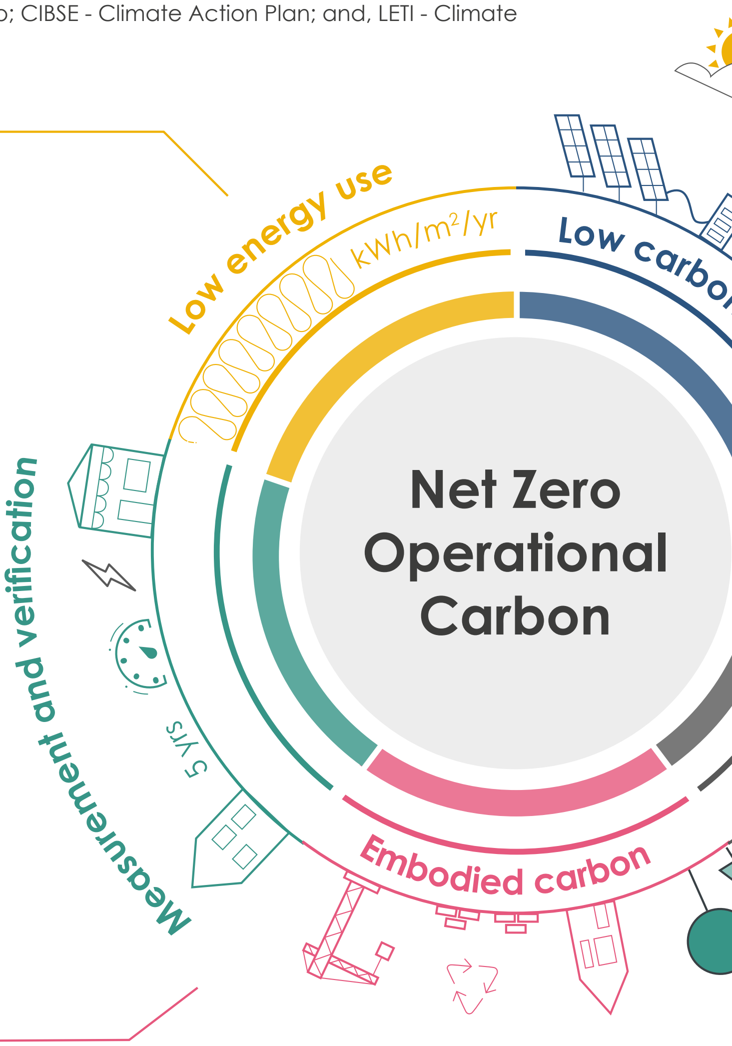
2. Building fabric is very important therefore space heating demand should be less than **15 kWh/m^2/yr** for all building types.

Measurement and verification

3. Annual energy use and renewable energy generation on-site must be reported and independently verified in-use each year for the first 5 years. This can be done on an aggregated and anonymised basis for residential buildings.

Reducing construction impacts

4. Embodied carbon should be assessed, reduced and verified post-construction.[3]

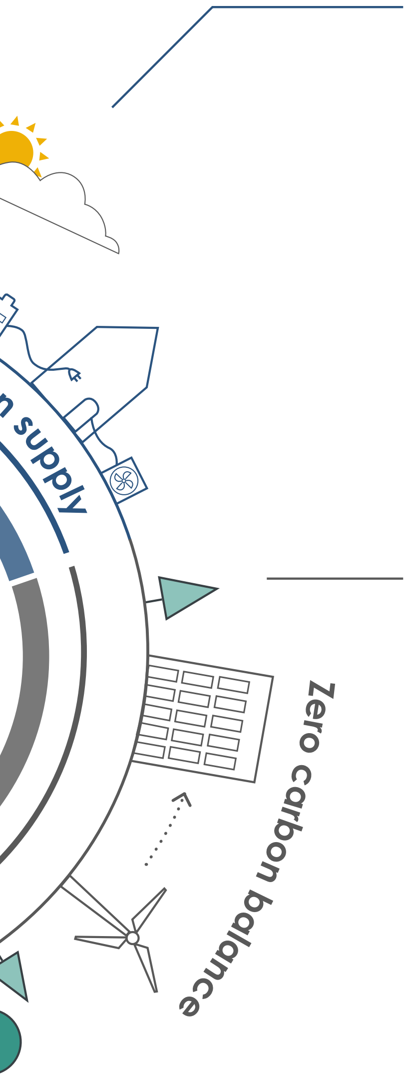


Developed in collaboration with:

LONDON ENERGY TRANSFORMATION INITIATIVE
UK GBC
BBP BETTER BUILDINGS PARTNERSHIP

Developed with the support of:

Good Homes Alliance
RIBA Architecture.com
CIBSE



Low carbon energy supply

5 **Heating and hot water should not be generated using fossil fuels.**

6 The average annual carbon content of the heat supplied (gCO_2/kWh) should be reported.

7 On-site renewable electricity should be maximised.

8 Energy demand response and storage measures should be incorporated and the building annual peak energy demand should be reported.

Zero carbon balance

9 A carbon balance calculation (on an annual basis) should be undertaken and it should be demonstrated that the building achieves a net zero carbon balance.

10 Any energy use not met by on-site renewables should be met by an investment into additional renewable energy capacity off-site OR a minimum 15 year renewable energy power purchase agreement (PPA). A green tariff is not robust enough and does not provide 'additional' renewables.

Notes:

Note 1 – Energy use intensity (EUI) targets
The above targets include all energy uses in the building (regulated and unregulated) as measured at the meter and exclude on-site generation. They have been derived from: predicted energy use modelling for best practice; a review of the best performing buildings in the UK; and a preliminary assessment of the renewable energy supply for UK buildings. They are likely to be revised as more knowledge is available in these three fields. As heating and hot water is not generated by fossil fuels, this assumes an all electric building until other zero carbon fuels exist, (kWh targets are the same as $kWh_{elec-eq}$). Once other zero carbon heating fuels are available this metric will be adapted.

Note 2 – Commercial offices
With a typical net to gross ratio, 70 kWh/m² NLA/yr is equivalent to 55 kWh/m² GIA/yr. Building owners and developers are recommended to target a base building rating of 6 stars using the BBP's Design for Performance process based on NABERS.

Note 3 – Whole life carbon
It is recognised that operational emissions represent only one aspect of net zero carbon in new buildings. Reducing whole life carbon is crucial and will be covered in separate guidance.

Note 4 – Adaptation to climate change
Net zero carbon buildings should also be adapted to climate change. It is essential that the risk of overheating is managed and that cooling is minimised.

Figure A0.1 - Net zero operational carbon one pager available for download from: https://www.leti.london/one-pager

A0.2: Actions by RIBA Stage

Operational carbon, future of heat, demand response and data disclosure

0 Strategic Definition

1. Identify a net zero carbon champion.

2. Identify project team responsibilities to achieve operational energy use targets including the calculation of operational targets, documenting assumptions behind these, managing risks and validating in-use performance.

3. Consider contractual incentives for achievement of performance targets.

4.Identify a project team member who can advise on demand response.

1 Preparation and Brief

1. Set clear intent for zero carbon targets and define what this includes, document boundaries and targets.

2. Set an energy use intensity target and embed within the brief

3. Discuss localised energy constraint issues with DNO.

4. Identify likely eligible demand response programmes at a national and regional scale.

5. Incorporation of data disclosure into BIM requirements.

2 Concept Design

1. Establish clear energy use targets, document targets and strategies to achieve this and share with all stakeholders.

2. Develop the concept design in accordance with critical design parameter recommendations in this guide. Specific aspects to consider at this stage include:

→ Building orientation
→ Building form factor
→ Facade glazing ratio
→ Likely occupancy patterns and operating scenarios
→ Facade glazing ratio
→ Technical systems integration.

3.Develop a preliminary operational energy model aligned to the Energy Use Intensity targets. Use this model to guide design throughout RIBA 2

4. Use the LETI Future of Heat Decision Tree when making decisions on heating and hot water systems.

5. Implement the most significant carbon/energy reduction measures in design including demand response and energy storage opportunities.

6. Highlight the roles and opportunities for overcoming performance gap, for example by following the BSRIA Soft Landings Framework.

3 Developed Design

1. Refine a full operational energy model for evaluation of predicted energy demand. Ensure this simulation goes beyond regulated energy and considers energy use from all items in the building.

2. Test proposed design changes using the energy model.

3. Update and document detailed targets and strategies to achieve these. Include design measures and assumptions of likely occupancy patterns and operating scenarios as well as strategies for long term adaptability.

4. Ensure proposed construction details are robust to support low energy and airtightness performance characteristics.

5. Ensure that the risk of overheating has been assessed and mitigated.

6. Develop demand response strategy and simulate potential impact.

7. Develop sub-metering strategy using LETI energy disclosure guidance. Heating and cooling energy consumption (kWh) should be metered separately to enable fabric performance to be assessed.

8. Establish a secure remote source for metered data to be transmitted over a communications network for aggregation and storage.

4 Technical Design

1. Update building energy model with latest design amendments, and ensure that operational energy targets are still being achieved. Document detailed targets and strategies to achieve these targets e.g. by creating a Building Performance Register.

2. Confirm envelope specification and complete detail design, ensuring good continuity of insulation and airtightness.

3. Check the suitability of the heating and hot water system using the LETI Future of Heat Decision Tree. Confirm HVAC systems type and performance specification.

4. Iterate demand response model with exact design data to gain a more accurate prediction of carbon savings and monetary gains. Ensure that specified equipment can integrate fully to carry out demand response processes and events easily.

5. Ensure specified metering is incorporated.

6. Include operational energy targets in the construction tender package, e.g. using a Design for Performance type of target and feedback loop.

7. Incorporate in contractors' prelims with guarantees to recalculate energy model if items in the register are changed or value engineered, to demonstrate that 'as built' project meets agreed operational targets. Create risk register and confirm responsibility for managing this during construction and commissioning.

5 Construction

1. Where possible, ensure the appointment of a clerk of works is responsible for quality checks.

2. Update energy model to account for any changes in the design or assumptions behind it and reject substitutions and omissions if achieving performance targets may be compromised by the changes.

3. Engage with the supply chain regarding the design targets of the project and where possible provide toolbox talks to help upskill contractors and to communicate the importance of quality construction.

4. Ensure the contractors understand commissioning requirements, including metering commissioning and validation of manual vs half hourly readings.

5. Ensure the contractor has quality monitoring processes in place to ensure proper installation of insulation, airtightness layer and mechanical equipment for the whole of the construction period.

6. Carry out benchmark inspections to clarify quality expectations and continue to monitor construction quality, including in-situ thermal performance tests, thermographic and air tightness testing.

7. Ensure the contractor understands the commissioning requirements.

6 Handover and Close Out

1. Review final construction including rectification work, for quality, including in-situ thermal performance tests, thermographic and air tightness testing.

2. Finalise as-built energy model to account for any changes in the design or assumptions behind it.

3. Ensure commissioning and testing is fully completed and witnessed and that the 'as installed' controls strategies, setpoints, commissioned flow rates, metering etc. are in line with the energy model.

4. Ensure the building user is trained and understands use of the building systems.

5. Ensure that planned demand response activities occur correctly as part of the commissioning process and that the initial setup parameters are recorded.

6. Ensure a suitably qualified individual understands the energy management and measurement systems. For further information regarding role and duties, refer to BBP better metering toolkit.

7. Ensure that performance data from sensors and meters are reconciled with main meter, spot meter and BMS readings and that logs are set up in BMS to facilitate long term monitoring of building performance.

7 In Use

1. For the first year of occupation both the building and the targets should be tuned to actual building usage patterns. Ensure a dual focus of improving accuracy of targets as well as improving building operation.

2. Ensure hourly energy consumption trends match operating hours.

3. Ensure the metering system is operating correctly and is regularly validated against utility meters.

4. Identify and track key efficiency metrics. Aim to track the fewest but most useful metrics.

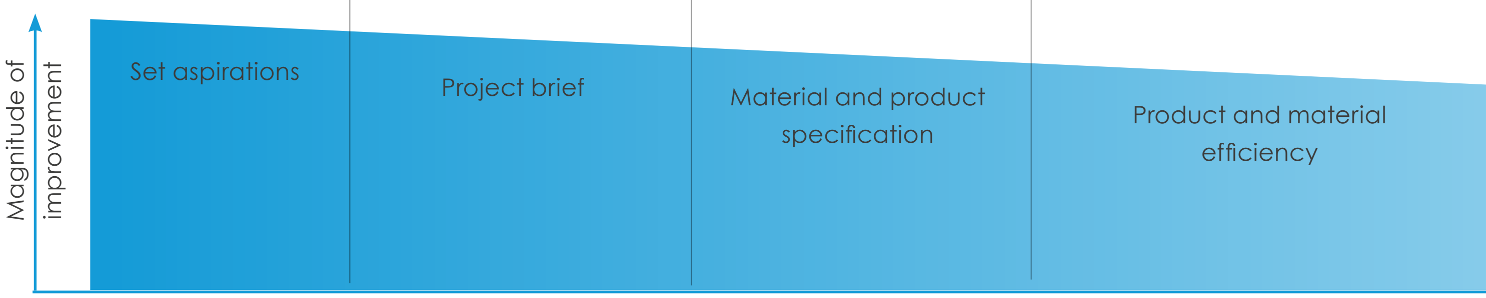
5. Assign an annual budget for monitoring energy use and tuning controls in response. Aim for monthly review and quarterly 'deep dive' analysis.

6. Line up energy efficiency assessments with post occupancy evaluation assessments to ensure occupant satisfaction with conditions in the building.

7. Upload total energy and heating energy consumption data to a public data platform for first 5 years post-completion.

The RIBA Stages 1-5 'For LCA Specialists' contents were extracted from the call out box 'Embodied and whole life carbon considerations through RIBA Plan of Works' with some amendments made by FARNETANI, Mirko. CIRIA Briefing - Whole-life carbon reduction strategy: good practice methodology. January 2017. Available from: https://www.ciria.org/ [Accessed 25 April 2019] .

0 Strategic Definition	1 Preparation and Brief	2 Concept Design	3 Developed Design
Embodied carbon - for the designer			
1. Discuss whole life carbon ambitions with client. 2. Review opportunity for retention of existing structure and building fabric and how the quantum of materials of the new build can be reduced.	1. Client brief to be developed: it should incorporate embodied carbon reduction targets. 2. Appoint a LCA specialist or design team member to be responsible for whole life carbon assessment.	1. Use rules of thumb guidance during concept to maximise opportunities for low carbon design. 2. Analyse carbon reduction options for building elements using numerical analysis.	1. Include requirements and targets for whole life carbon in specifications and tender documentation at start of procurement. 2. Have discussions with the potential contractors and subcontractors around whole life carbon targets, asking for options for improvement and including carbon questions on tender return forms. 3. Continue numerical analysis and use material guides to optimise material specification.
Embodied carbon - for the Life Cycle Assessment (LCA) specialist			
	1. Set initial embodied carbon targets using rule of thumb guidance and benchmarks. *OUTCOMES:* Early recommendations on low carbon options ahead of RIBA Stage 2.	1. As the design develops, provide more detailed analysis of the options around the key building systems: frame, floors, envelope. This is discussed with the design team through workshops. *OUTCOMES:* More detailed analysis and recommendations of the agreed design options. Improved understanding of embodied and whole life carbon within design team.	1. In depth analysis of the elemental and component parts of the entire building, identifying specific materials, products and lifespans, to generate a whole life carbon budget baseline. 2. Assess low carbon alternatives to the baseline. Agree a carbon reduction target - either percentage or absolute. *OUTCOMES:* A whole life carbon budget, representing the total carbon emitted over the lifetime of the building, and an associated carbon reduction target. Initial carbon reduction option list, which will be further developed during technical design stage.



4 Technical Design	5 Construction	6 Handover and Close Out	7 In Use
1. Finalise requirements and targets for whole life carbon in specifications and tender documentation at start of procurement. 2. Finalise requirements with the potential contractors and subcontractors around whole life carbon targets, asking for options for improvement and including carbon questions on tender return forms. 3. Continue numerical analysis and use material guides to optimise material specification.	1. Engage with contractors to reduce waste. 2. Review alternative products and materials selections proposed by the contractor against technical and performance standards and against the whole life carbon requirements. 3. Prepare for post-completion analysis by collecting numerical data through the construction phase.	1. Undertake post completion analysis using as-built information to assess upfront embodied carbon.	1. Recommendations regarding embodied carbon reduction strategy over the in-use stage should be followed throughout the building life cycle including at the end of life stage.
1. Update whole life carbon budget to include design development and finalise the carbon reduction options list. 2. Send pre-procurement Request for Information (RFI) to suppliers to collect carbon data in order to provide supplementary information for supplier selection. Review returned RFIs and analyse the environmental credentials of procurement options. *OUTCOMES:* Agree carbon reduction targets and carbon reduction options list in order to influence specifications. A list of recommended low-carbon supplier. Assess design against embodied carbon targets. Ensure specifications include embodied carbon of materials. Recommend a list of suitable low carbon suppliers.	1. Send RFIs to suppliers in order to receive construction carbon data and verify the environmental credentials. 2. Undertake building site monitoring through monthly site logs and construction progress reporting. *OUTCOMES:* Facilitate gathering of data for the construction stage analysis and achieve the agreed carbon reduction targets.	1. At the end of site works, the contractor should confirm the final carbon related data to the LCA specialist. Develop the practical completion carbon report. Align the design stage carbon targets with what was achieved at the end of construction. *OUTCOMES:* Practical completion carbon report to be issued to the client.	1. Embodied carbon reduction strategy to include in-use and end of life stages. *OUTCOMES:* Client to have relevant information to continue embodied carbon reduction strategy throughout in-use and end of life stages.
Material and product declaration	Material and product verification	As build carbon report to client	In-use carbon report to client

A1.1: 'Top-down' Calculations

Methodology: 'Top-down' calculations

If we are to achieve net zero carbon across the building stock, the Energy Use Intensity (EUI) for every building must not exceed the proportion of zero carbon energy available. LETI has taken the 2030 and 2050 forecasts for renewable energy generation in Great Britain, and broken down the proportion of that energy which might reasonably be made available to buildings. This results in a target or 'budget' EUI for the main archetypes, namely domestic, office, retail and industrial. Note, all calculations are indicative and should be refined in future. The approach and data sources used for calculations are outlined in further detail below.

→ **Forecast of total renewable generation** – National Grid's 2018 Community Renewables Future Energy Scenario[1] was used to estimate the amount of renewable capacity, in TWh, that would be available to Great Britain in 2030 and 2050.

→ **Total energy consumption per building use type** – Data tables of Energy Consumption in the UK[2] provided final energy consumption figures, in ktoe, per building use type. This was used to establish the percentage of energy that was consumed per building use type. This percentage dictates the amount of future renewable energy generation that would be assigned to each building use type, assuming that the split of office, residential, industrial and other building types across the UK remains constant.

→ **Total building areas** – Non-domestic rating: Business Floorspace tables[3] provided information on the total floorspace (in m^2) for office, industrial and retail buildings across England and Wales. Indicative areas for Scottish floorspace were taken from Commercial Real Estate and Scottish Economy[4]. It is understood that the Scottish Government does not keep statistics on floorspace. An updated estimate for Scotland would be useful for improving the accuracy of the 'top-down' modelling.
An estimate for the number of domestic dwellings in Great Britain was found by comparing the Office for National Statistics' Families and Households dataset[5] to the Northern Ireland Housing Statistics 2017-18[6]. Total domestic floor area in Great Britain was then estimated by multiplying the number of dwellings by the average useable floor area for properties in England, from the England Housing Survey Headline Report 2017-18[7].

→ **Forecast building areas** – Estimates for the total domestic floor area in 2030 and 2050 were calculated by assuming a 1% increase in new build completion per year.
From analysing trends in non-domestic floorspace using the Valuation Office Agency's data tables[8] the total floor area for office, industrial and retail buildings was assumed to remain reasonably constant and thus the total floor area for 2030 and 2050 would be approximated by 2018 values.

Using the above information, available renewable generation per m^2 for domestic, industrial, office and retail in 2030 and 2050 was calculated.

Effectively this results in a target EUI figure for domestic, industrial, office and retail buildings that could be compared with the results of the 'bottom-up' calculations.

Top down modelling results	Community renewables scenario available generation - 2030 (kWh/m².yr)*		Community renewables scenario available generation - 2050 (kWh/m².yr)*	
Building type	**Renewable energy only**	**Renewable energy plus nuclear**	**Renewable energy only**	**Renewable energy plus nuclear**
Domestic	27	29	37	43
Industrial (without processes)	27	30	38	44
Office	62	67	85	99
Retail	49	53	67	79

(Renewable energy generation allocated to use type (kWh))/
(Forecast total floor area of building use type (m²))

* area is NIA
Note: Community renewables is the most optimistic of the FESs with regards to forecast renewable capacity by 2050. For renewable plus nuclear, only the Two Degrees scenario forecasts more capacity than community renewables (by 5TWh).

Figure A1.1 - Top down modelling results

UK Green Building Council - 'Paris Proof' targets

The UK Green Building Council (UKGBC) has also undertaken 'top-down' calculations to determine energy performance targets for offices based on the available supply of zero carbon energy in 2050. Through consultation and direct engagement with stakeholders, UKGBC identified a need for 60% reduction in energy use from the office sector which translates to the 'Paris Proof' targets outlined in Figure A1.2.

Net zero trajectory for offices

For offices looking to achieve net zero carbon for operational energy, the Paris Proof targets offer an outcome-based approach to setting energy performance targets, Figure A1.3 sets out a trajectory for tightening performance targets over the next fifteen years for offices targeting net zero. The trajectory is based upon meeting current best practice performance over the next five years, with ambitious steps down towards the Paris Proof targets by 2035.

The expectation is that individual offices targeting net zero carbon should seek to meet and exceed the performance levels set out by the trajectory before the procurement of renewable energy or offsets. The principles from UKGBC's Net Zero Carbon Buildings Framework should then be followed to demonstrate how net zero for operational energy has been achieved. Where the energy performance targets are not achieved, this should be publicly disclosed with an action plan setting out how the target will be met in subsequent years.

The trajectory does not differentiate between new and existing offices, but it is expected that new offices should aim to achieve the Paris Proof targets as soon as possible. Additionally, further consideration may be required for upgrading existing offices, including understanding the embodied carbon impacts from retrofit and any concessions for heritage buildings.

These targets are intended to signpost to stakeholders from across the offices sector the magnitude of energy reductions required to achieve net zero by 2050. They

UKGBC energy performance targets for existing offices

		Interim targets			Paris proof target
Scope	**Metric**	**2020-2025**	**2025-2030**	**2030-2035**	**2035-2050**
Whole building energy	kWhe/m² (NIA)/yr	160	115	90	70
	kWhe/m² (GIA)/yr	130	90	70	55
	DEC rating	D90	C65	B50	B40
Base building energy	kWhe/m² (NLA)/yr	90	70	55	35
	kWhe/m² (GIA)/yr	70	55	45	30
	NABERS star rating	4.5	5	5.5	6
Tenant energy	kWhe/m² (NLA)/yr	70	45	35	35

Figure A1.2 - UKGBC Energy performance targets for existing offices targeting net zero carbon for operational energy[9]

Figure A1.1 - Top down modelling results will challenge the construction and property sector to re-imagine the way offices are designed, constructed and operated, including moving towards in-use performance as the verifiable metric for energy.

For more information on UKGBC's Paris Proof targets, please visit: https://www.ukgbc.org/news/consultation-on-energy-performance-targets-for-offices-launched-to-target-net-zero/

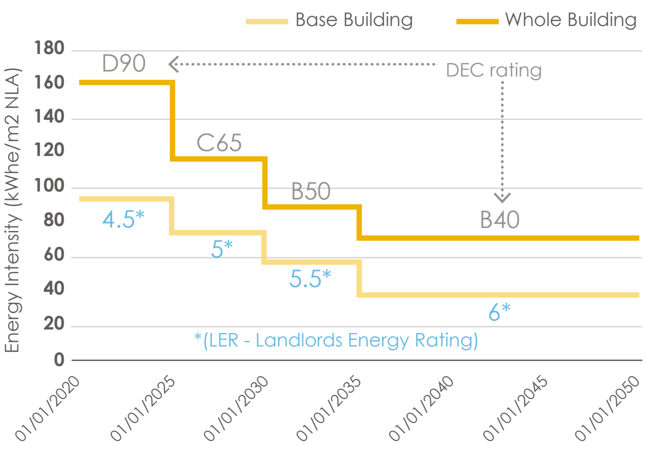


Figure A1.3 - UKGBC -Trajectory for offices targeting net zero carbon (also indicating equivalent NABERS star rating)

Dutch Green Building Council - 'Paris Proof' targets

The Dutch Green Buildings Council has also developed the 'Paris-proof' methodology[10] for quantifying the order of magnitude of renewable energy that is likely to be available for each building type in the Netherlands. Their methodology allocates the expected practical availability of renewable electricity between national sectors (transport, industry, buildings etc..). For the building sector, it subdivides the annually available renewable energy between the various main building types. The following is an extract of their conclusions:

Offices:
→ 50 kWh/m^2.yr

Retail:
→ Shop with cooling, such as a supermarket: 150 kWh/m^2.yr
→ Shop without cooling: 80 kWh/m^2.yr

Education:
→ Primary education: 60 kWh/m^2.yr
→ Secondary education: 60 kWh/m^2.yr
→ Colleges and universities: 70 kWh/m^2.yr

Healthcare:
→ Hospital: 100 kWh/m^2
→ Daycare with accommodation: 80 kWh/m^2.yr
→ Daycare without overnight stay: 90 kWh/m^2.yr
→ Medical group practice: 80 kWh/m^2.yr

Logistics / industrial:
→ Industrial building with cooling: 80 kWh/m^2.yr
→ Industrial building without cooling: 50 kWh/m^2.yr

A1.2: The Performance Gap

Summary

A prerequisite to implementing the transition to operational net zero targets advocated by LETI is bridging the gap between design and actual energy performance. Legislating for better standards has no effect if the buildings that are produced do not perform in practice.

In order to create the boundary conditions for a shift in culture to happen, LETI propose to institute an Assured Performance Framework (APF) and dutyholder regime. The APF revolves around independent reviews of design, construction and operation linked to RIBA Plan of Work stages, feeding learnings back into the loop using BSRIA Soft Landings principles. Central elements to this will be clear accountability through an accredited Performance Coordinator responsible for managing performance from inception through to completion and beyond; an overarching system for oversight of competence; a Complaints Resolution Service giving consumers a stronger voice; and more effective enforcement to deter non-compliance. LETI's proposals align with the proposed reform of the building safety regulatory system and proposed legislation to provide better redress for purchasers of new build homes. As such, it is hoped that there will be a legislative lever to uptake the proposal within the next iteration of the Building Regulations.

Background

The performance gap can typically be described as the deficit between energy predictions from building compliance tools and actual measured energy in-use. This determines whether a building and its systems work as expected when occupied and the extent of the gap where not. Expectations may be defined by regulatory targets, client and other requirements. The performance gap does not solely relate to energy, it has an impact on a number of variables including fire safety, acoustic performance, comfort, lighting and design quality. As such, a holistic approach is needed.

The current regulatory approach based on modelling for compliance (as opposed to modelling for performance) does not allow the size of the performance gap in the UK built environment to be pinpointed. The national standard assessment methodology for compliance was conceived for comparison purposes and relies upon a standardised set of operational assumptions. One of its key deficiencies is in disregarding unregulated loads, whose proportion of total energy use varies between sectors, accounting for more than 25% in non-domestic buildings[11]. Statistical evidence of performance gap in new buildings from a number of field testing programmes is consistently revealing underperforming envelopes (design vs as-built airtightness and thermal transmittance) leading to higher heating demand [12,13,14]. Using conservative assumptions to normalise the difference in heat balance scope, the Passivhaus Trust[15] has worked out that an average performance gap expressed as the overall additional energy use of a new build house amounts to 40% compared to its EPC modelling and anecdotal evidence suggests that it can be up to 500%. In order to deliver on LETI's net zero performance-based targets, it is therefore crucial for this gap to be closed. Good design alone is not sufficient, we need to measure and understand the performance gap in order to identify ways of closing it. This will be fundamental alongside the integration of efficient fabric, systems, technologies and performance monitoring to achieve net zero buildings in operation.

This briefing paper breaks down the causes leading to a building failing to achieve its design intentions and suggests methods for closing the performance gap based on three pillars – setting realistic targets, ongoing performance monitoring and reduction strategies applied to the full building life cycle. Included in our recommendations is the institution of an independent assured performance framework and dutyholder regime.

Causes of performance gap

It is possible to identify key variables that, have a knock-on effect on performance, as shown in Figure A1.4.

A closer look into underperforming envelopes, services and wider environmental indoor quality contained in a growing body of literature unveils their relationships with sub-optimal practices throughout the entire process, and is detailed in the Table on the following page.

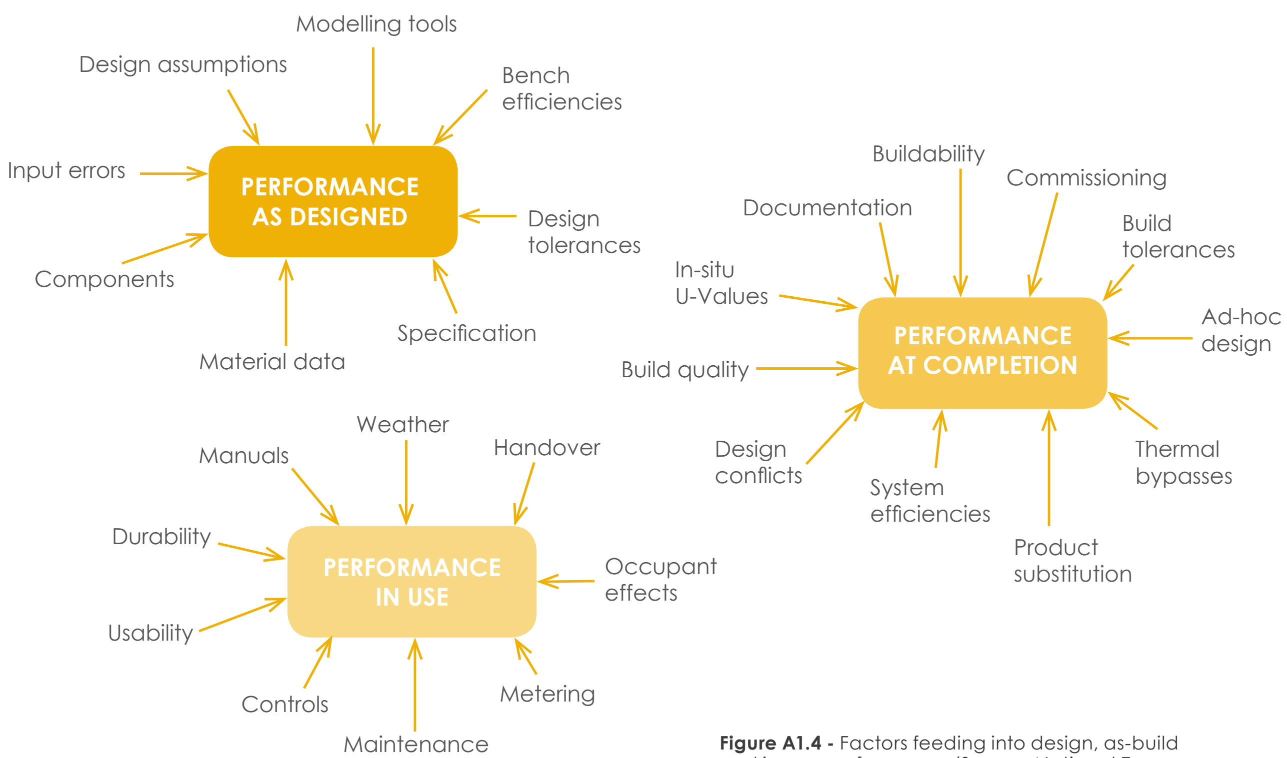


Figure A1.4 - Factors feeding into design, as-build and in-use performance (Source: National Energy Foundation, 2015).

Common causes of underperformance

Causes of underperformance	Diagnostic tools
Building fabric	
→ Flawed design calculations (assumptions, inputs inaccuracies). → Workmanship → Poor handling and storage of materials on site, no understanding of their energy impact → Low quality of materials compared to design specifications → Value engineering in favour of lower performance cost-engineered alternatives → Poor insulation detailing in particular at the interface, both design (use of default thermal bridging coefficients) and construction phase → No airtightness strategy → Services penetrations interrupting the continuity of the airtightness layer.	→ Fabric in-situ testing – stand-alone (heat flow meter) or whole envelope (co-heating test) → In-situ airtightness tests – stand-alone (pressurisation equipment, smoke test) or whole envelope (hot wire anemometer, tracer gas → Inspection of construction quality (infrared thermography + expert diagnostic investigation) → Installation quality checks (photographs during construction).
Building services	
→ Lack of commissioning of services and suboptimal controls zoning / system communication → Over-sized systems → Controls unfit for intended users of the building → Poor coordination between designers and contractors → Poor standard of installation / commissioning / handover / maintenance.	→ Installation and commissioning checks — evaluation of operation and settings of the system → Measurement and verification. In particular mechanical ventilation (power measurement + volumetric airflow measurement → Utilities metering, ideally sub-metered energy use.
Indoor environmental quality	
→ Overheating due to suboptimal environmental design (orientation, thermal inertia, glazing ratio, solar shading etc..), fabric and systems design (glazing specifications e.g., total solar energy transmittance, ineffective ventilation strategy, space heating controls difficult to operate or faulty, uninsulated pipework contributing to unwanted heat gains…) → Poor indoor air quality due to ineffective ventilation mechanisms, including poor maintenance of mechanical ventilation → Design is not user-centric (health and wellbeing not central in design).	→ Services' visual inspection and performance testing → Moisture monitoring (protimeter) → Temperature, relative humidity and CO_2 / VOCs / NOx monitoring → Occupant surveys using standardised questionnaire e.g. Building Use Studies (BUS) surveys → Qualitative semi-structured interviews with the occupants.

Figure A1.5 - Review of common causes of under performance across building envelopes, services and indoor environmental quality.

Closing the performance gap

In simple terms, closing the performance gap relies on three key pillars: (i) set realistic targets, (ii) monitor ongoing performance, and (iii) put in place a process to reduce energy use against target.

For existing buildings, target-setting can take the form of applying benchmark data or commissioning a detailed simulation model. For new buildings, closing the performance gap starts at the concept design phase. Preliminary performance and energy use targets should be set, and detailed predicted energy use modelling undertaken to support the design process. Target-setting should encompass the full spectrum of intended operational parameters and should be undertaken with input from project stakeholders including building users.

For new buildings, careful monitoring of the project delivery during construction and handover must take place, followed by verification and commissioning to ensure that the design is realised in the delivery of the building. Performance targets should be refined and linked to the monitoring system to enable simple ongoing comparison.

Throughout operation, ongoing monitoring would identify areas to focus on in order to drive down energy use. For the first year of operation a 'bottom-up' approach may be useful, with each energy end use compared to its predicted performance — this process would help refine the targets as much as it will identify opportunities to reduce consumption.

It is critical to ensure that performance is monitored through the life of the building — changes to maintenance strategies, occupant pattern and other factors mean that 'set and forget' is almost certain to result in performance problems over time. Generally a 'top-down' approach is recommended: high level reporting against overall targets with a 'deep dive' to end-use level where problems are identified.

Against this backdrop, a more effective accountability framework from design through construction and occupation of the buildings is crucial to create a real shift in culture across the industry. Clearly identified individuals directly accountable for performance should be mandated. This is similar to the reform for the building safety regulatory system proposed after the

Figure A1.6 - How to close the performance gap

Hackitt's review, and is in line with the Government's wider commitment to improve redress in the housing market. Such a dutyholder regime would provide clear accountability for managing performance so that consumers' interests in getting the expected build quality are protected, whilst holding developers to account.

The new regime ought to give consumers a stronger voice and set out clear routes of escalation if things go wrong. A bespoke Complaints Resolution Service could be established as a single point of access where consumers know they could turn for help.

Finally, enforcement action shall be strengthened to deter non-compliance with the new regime. Effective powers of intervention and sanctions shall be given to the overseeing regulator.

Conclusion

The causes of the performance gap are vast and varied, and span across many stakeholders.

Closing the performance gap is instrumental in achieving net zero carbon, making addressing it a priority to a successful transition to outcome-focused targets in the built environment. In order to move away from the status quo, LETI advocates focusing on performance.

We support the institution of an independent assured performance process. This could take the shape of independent design and construction review and support input linked to RIBA stages.

→ RIBA 0-2: Review of realistic targets that encompass all energy uses in the building and the underpinning environmental design vision and strategy.

→ RIBA 3-4: Detailed review of design from a performance angle, feeding findings back into the loop before construction works commence. Appropriate energy modelling (i.e. modelling for reality as opposed to compliance) to ensure that energy performance is not significantly affected among the many trade-offs that must be made through the design process.

→ RIBA 5-6: on-site supervision carried out by a named individual. Robust testing and verification regime.

→ Operation: continuous monitoring of energy performance. Ongoing reward and recognition for meeting performance targets creates incentive to further reduce consumption and improve user satisfaction. Strategies to include approaches for putting building users at the heart of the performance question through post occupancy evaluation.

The legislative mechanisms required to be put in place are outside the scope of this document. Nonetheless it is advocated that the role of qualified and accredited Performance Coordinator, responsible for all aspects of performance from inception to completion (in a similar fashion to the PAS 2035 Retrofit Coordinator) is created. This, alongside the existing Government's initiatives to strengthen quality and standards putting the consumer at the centre of the journey, would create a market and the conditions for better performance.

Critical to all of this will be feeding lessons back into the loop using Soft Landings and standardisation of procedures.

References

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13 - 'Building Performance Evaluation Programme: findings from non-domestic projects. Getting the best from buildings' Innovate UK (2016)

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15 - Passivhaus: the route to zero carbon? London: Passivhaus Trust (2019)

A2.1: Embodied carbon reduction calculations

Summary

This Appendix provides a description of the process for carrying out embodied carbon calculations. It also goes into details on the tools available and how to consider operational energy within whole life carbon calculations. There is a section on the Scope of Work for life cycle assessment that provides supporting information for how to approach and engage a consultant.

Conducting life cycle assessment (LCA)

Embodied carbon refers to the amount of greenhouse gas emissions created during the processes of material extraction, manufacturing, transport, construction, maintenance, repair, refurbishment, replacement, demolition and disposal. **Whole life carbon** refers to embodied carbon plus emissions related to energy and water use. The purpose of assessing WLC is to move towards a building or a product that generates lower carbon emissions over its whole life.

This can be measured through a **life cycle assessment** which accounts for emissions at every stage of the entire life cycle of a building's materials and products. Typically, a LCA of proposed building consists of 4 steps:

1. Define goal and boundaries.
2. Estimate quantities of materials, products and processes in the building.
3. Assess the carbon equivalent emissions for each material/product and process and then sum them to obtain the overall carbon footprint (See Figure A2.1).
4. Interpret the results, refine and re-iterate if needed.

Inventory	x	Impacts	=	Total
Estimate of quantities of materials and processes in building		Estimate of environmental impacts for each material and process		Estimate of total environmental impact of building

E.g.

100 kg steel	x	0.43 $kgCO_2e$	=	43 kg CO_2e
50 kg glass	x	1.064 $kgCO_2e$	=	53.2 kg CO_2e

Figure A2.1 - Simple example of LCA calculation process (Source: Carbon leadership forum practice guide 2019 p11)

1. Define goal and scope

The first step is to define the goal, meaning the reasons for carrying out the LCA study. To ensure consistency, it is necessary to define the boundaries for the calculation.

The site scope – a clear indication of the project site and which buildings are included within the study.

The building element scope – a clear indication of the building's parts included within the study. It is important to have a consistent approach in carrying out a building LCA with regard to which building parts should be considered and assessed. The BREEAM New Construction 2018 UK – Mat 01 guide provides a reference for the industry, defining lists of In-Scope and Out of Scope building elements based upon the RICS New Rules of Measurement (NRM) classification system (N.B. this is not applicable for fit-out, Cat A, Cat B assessments).

SIGNPOST *Embodied Carbon Primer - Appendix 11 - In scope and out of scope*

Measurement unit - which unit should the results be presented in. For embodied carbon, it is usually kg of CO_2 equivalent (CO_2e) over 100 years.

The (reference) Study Period - period of time considered for the LCA study, this will affect the results related to the in-use stage, due to replacement of building parts and systems. The study period should be defined in order to establish the building's whole expected life and the related service life of building parts and systems. 60 years is often taken as the study period.

The system boundary / Life cycle stages - which life cycle stages (as defined by EN 15978) are considered in the LCA study. The life cycle stages assessed must be comparable for each iteration of the assessment.

SIGNPOST *Embodied Carbon Primer - Appendix 3 - How to measure embodied carbon*

Figure A2.2 shows the activities within each stage (A-C) and supplementary Module D as laid out in EN 15978:

→ Cradle to Gate: Stage A1-A3.
→ Cradle to Practical Completion of Works: Stages A1-A3 & A4-A5.
→ Use: B1-7
→ End of Life: C1-4
→ Cradle to Grave: Stages A-B-C
→ Cradle to Cradle: Stages A-B-C & Module D

There are some controversies concerning the methodology of specific subjects which need to be clearly defined such as Biogenic carbon (often also called Timber sequestration).

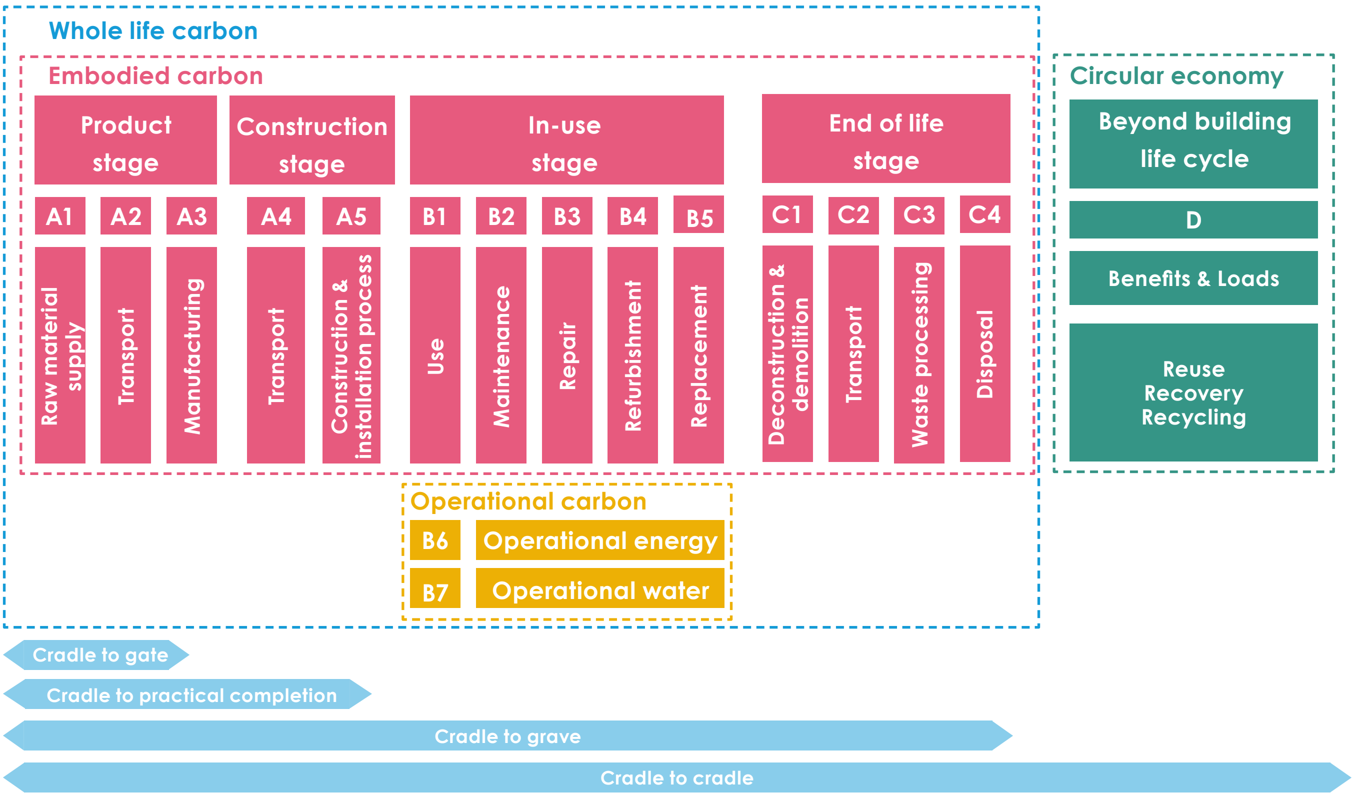

Figure A2.2 - System Boundary: EN 15978:2011 Display of modular information for the different stages of the building assessment

2. Estimate quantities of materials, products and processes in the building

Embodied Carbon

In the case of the embodied carbon component of a LCA of a building, the estimate of quantities of materials takes place at two different scales.

At the building level: Listing the quantities can be done manually by listing all materials, products and systems within the building, however it is be recommended to use BIM models to identify the different quantities.

At the product level: Once all products are identified within the building, the inner parts and processes involved in making the product, in use and end of life of the products needs to be listed as well. This is a very tedious and time-consuming process; therefore, design teams should refer to Environmental Product Declarations from manufactures or other generic information from the Industry which already have calculated the environmental impacts of the product throughout the life cycle stages.

Operational Carbon

It is important to realistically estimate the operational energy of the building. For design stage calculations use predictive modelling allowing for a performance gap to estimate energy consumption. If this is not available use benchmark figures relevant to the building type and location. Do not use SAP/SBEM (calculations carried out for Building Regulations) for calculating operational energy as these calculations are for compliance only and do not predict energy consumption.

SIGNPOST *Embodied Carbon Primer - Appendix 3 - How to measure embodied carbon*

3. Assess the environmental impact

Embodied Carbon

At building level, this requires multiplying the quantities of the material product with its environmental impacts for each life cycle stage of the building. It is recommended to use specific tools which gather all the information in the same place with an inbuilt database. BIM based LCA tools have the advantage, compared to other tools, to be linked to the BIM model which detects automatically the different material quantities of building parts within the building.

SIGNPOST *Embodied Carbon Primer - Appendix 3 - How to measure embodied carbon*

Different life cycle impact assessment methods currently exist, so the method used by the tool at building level should be consistent with the methods used at the product level (from EPDs for instance).

Operational Carbon

It is important to realistically estimate operational carbon emissions. It is recommended to use annual lifetime carbon emissions factors, at present this is 0.07 $kgCO_2/kWh$ for the average content of the UK grid over the next 30 years.

4. Interpret the results, refine and re-iterate

Conducting life cycle assessments is an iterative process by nature. As the design teams are exploring different design options, it is a tool to inform on the environmental impacts to help make decisions on what is the best solution from an environmental point of view.

The below step sequence lists how to model embodied carbon reductions:

1. Create a 'baseline model'
2. Follow the 'rules of thumb' in the Embodied Carbon Primer.
3. Understand the big-ticket items – the building elements that have the most impact
4. Develop the carbon reduction strategy
5. Determine an 'optimised model' and '% carbon reduction'

SIGNPOST *Embodied Carbon Primer - Appendix 6 - Rules of thumb*

The baseline model

The baseline must be defined using the first design iteration before any carbon saving measures are introduced. It is imperative to build a consistent and solid baseline model in order to calculate the reductions brought about by any carbon reduction measures. The baseline will highlight which building elements generate the most carbon emissions, allowing the designer to focus attention on areas where greater carbon mitigation interventions are possible.

SIGNPOST *Embodied Carbon Primer - Appendix 12 - Baseline specifications*

Embodied Carbon reduction strategy

Subsequently, an embodied carbon reduction strategy would identify a list of alternative measures and quantify the magnitude of carbon abatement that each would provide.

Life cycle assessment tools

A number of tools to conduct life cycle assessment for buildings exist today. They can differ by their Life Cycle Impact Assessment (LCIA) methodologies, data source, standards they follow, and standards they comply with. Appendix 4 of the Embodied Carbon Primer gives a few examples to demonstrate the range and explains the advantage of BIM (plug-in) based tools.

This appendix also provides some valuable pointers on what to consider when using LCA tools such as geographical location of the database, data used at different project stages and the importance of breaking the project (and BIM model) down into more accurately measurable components.

SIGNPOST *Embodied Carbon Primer - Appendix 4 - LCA tools*

Scope of work for life cycle assessment

To meaningfully inform a carbon reduction strategy, whole life carbon calculations should be carried out through a life cycle assessment (LCA). This can be carried out by an in-house specialist or by a dedicated LCA consultant.

Firstly, it is essential that a client brief is developed to outline the client's ambitions and objectives. For example, the brief may include a target expressed in kg CO_2e/m^2, a percentage reduction in embodied carbon, or outline a goal such as 'to create the client's lowest embodied carbon office building'. For detailed guidance read UKGBC's 'Embodied Carbon: Developing a Client Brief'.

SIGNPOST *Embodied Carbon Primer - Appendix 2 - Scope of work for LCA*

A2.2: Materials Guide

Summary

When it comes to materials choices there is no single solution to designing low-embodied carbon buildings. A key consideration is to ensure that each material should be chosen only where it is the best at performing the function it is required to perform with the lowest whole life carbon impact. It may be that higher embodied carbon materials are chosen due to their roles in reducing operational carbon over a building's lifetime.

Wherever possible, local reclaimed materials should be used as this also reduces delivery distances and packaging. An Environmental Product Declaration (EPD), obtained via a thorough Life Cycle Analysis (LCA) of a material or component can be used to assess the environmental impacts of a specification choice. The recyclability of the material at the end of the building's useful life should also be considered.

For any material that is being specified in a building, always ask suppliers:

→ Do you have an EPD?
→ How can your product be recycled/reused?
→ What is the embodied carbon of your product, and what are you doing to reduce this?

Concrete

Concrete is utilised for infrastructure, foundations, floors, walls, structural frames. As a mixture of cement (usually Ordinary Portland cement (OPC)) and aggregate, concrete can be produced to different compressive and tensile strengths and with variations in aggregates and binders. Higher compressive strength will usually come at a cost of higher embodied carbon. OPC, the binder in concrete, is produced from clinker (from heated limestone and minerals) and gypsum.

Key considerations:

→ Slimming off excess where structurally viable to save in material usage;
→ Reducing and substituting OPC with recycled or sustainably-sourced content, whilst ensuring strength and integrity is retained (examples: GGBS and PFA);
→ Considering a structural grid and superstructure design to enable different use types and deconstruction for use elsewhere when the building has got to the end of its life;
→ Considering reusable plastic formwork;
→ Standardising detailing to enable repetition of reinforcement and also to enable formwork to be re-used multiple times.

Timber/wood

Wood should be sourced from sustainably managed forests. Carbon sequestration rates in trees are dependent on many variables – maturity, forest type, local climate, soil and forest management - the rate reduces as a tree reaches maturity.

Key considerations:

→ Sustainable sourcing is vital and deforestation is a serious issue. Only specify timber from sustainably managed sources;
→ Most engineered timbers are currently shipped in to the UK, consideration should therefore be given to the carbon emissions of transportation when compared with locally available materials;
→ Engineered timbers that use glues/adhesives in

the lamination process may be more difficult to reuse;
- → Products such as OSB (oriented strand board) are made using glues and resins which can emit VOCs, affecting indoor air quality;
- → Treatment of timber may affect end of life reusability;
- → Also consider reversible mechanical fixings or interlocking strategies which require no additional materials.

Brick

Brick is a popular choice for walls. Brick is produced by cutting a 'slug' of clay into units which are fired at around 2,000 degrees. Emissions come from both the fossil fuels used in the heating and from the processes related to all clay products (e.g. extraction). On larger scale buildings brick slips, mounted on steel fixings and used as a rainscreen, are often used to save time and costs. However, brick slips have a higher embodied carbon on a per kilo basis due to the brackets and fixings.

Key considerations:

- → Local reclaimed brick should be sourced wherever possible. An unfired brick system with much lower embodied carbon may be suitable for internal non-load bearing walls and can also help with humidity regulation;
- → For a circular approach, it is advised to use a mortar which is softer than the brick. Hard concrete mortars will not remove easily from brickwork, resulting in damaged and broken bricks;
- → Damaged bricks can be ground up and used in aggregates;
- → Consider using a mortar mix that is low in embodied carbon but strong enough for the purpose while allowing the brick to be easily reclaimed.

Structural steel

51% of global steel is used for construction. Steel is used in a wide range of construction projects ranging from single dwellings to large scale infrastructure.

Key considerations:

- → To help with re-use, use standard bolted connection details and clamped fittings in preference to welded joints;
- → Where feasible, ensure that steel is free from coatings or coverings that will prevent visual assessment of potential for re-use; and,
- → Identify the origin and properties of the component by bar-coding, e-tagging or stamping, and keep an inventory of products (material passport) so that products can be re-used once the building has reached.

Aluminium

The production of primary aluminium requires very high electricity consumption almost 10 times that of steel. Owing to the very energy intensive processing involved, embodied carbon is very high, especially when used in larger volumes. Aluminium is highly recyclable, with properties that do not diminish as the material is re-used. Worldwide, around 75% of all aluminium produced is still in use. Recycling uses only around 5% of the energy needed to produce primary aluminium. Inventories of all aluminium components should be kept to ensure all material is tracked and can be recycled in the future.

Key considerations:

- → Long transportation routes in between extraction, processing and fabrication adds to embodied energy. As well as energy intensity, bauxite processing is very water intensive;
- → The residue from aluminium processing is in the order of 120 million tonnes per year and is toxic to animal and plant life. Most of this residue is stored in holding ponds as there are virtually no further suitable applications for re-use.

Glass

Soda-lime glass accounts for 90% of manufactured glass. It is made up of 70-74% silica, along with sodium carbonate, lime, magnesium oxide and aluminium oxide in order to enhance its properties. With its unique translucent properties, glass has a variety of uses. Recycled glass can have a second use as insulation or aggregate.

Key considerations:

- → Glass requires the use of non-renewable natural raw materials - sand and minerals;
- → Consider the whole life carbon of any project - low embodied carbon is a false economy if heat is easily lost in the operational phase; and,
- → Where framing is required, timber is usually the best option. It has a longer useful life than PVC and superior thermal performance than metals.

SIGNPOST *Embodied Carbon Primer - Appendix 8 - Material guides*

A3.1: Hydrogen

Hydrogen conversion of natural gas networks

The following publications by and for the Committee on Climate Change (CCC) assess the potential for hydrogen as part of a net zero carbon United Kingdom. In essence, the indications are that hydrogen has a key role to play, but should be focused on selective sectors and perhaps regions. When 80% carbon emissions reductions were considered as target, hydrogen conversion of natural gas networks was seen to be cost comparable with other scenarios. However, conversion of the national gas network as part of achieving net zero carbon is seen to be a significantly more expensive option.

The large-scale conversion of natural gas to hydrogen does produce CO_2. Therefore, for this technology to be considered net zero carbon, it would need to be subject to Carbon Capture and Storage (CCS). Replacing the gas supply network would also involve very large-scale annual storage of hydrogen to meet the winter peak heating demand profile, particularly as its conversion may need to use summertime 'spare' renewable grid electricity. These issues significantly impact on the overall costs of this option. However, there is lower-cost potential for regional gas grid conversion local to where natural gas comes ashore, where there are geological opportunities for CCS, in association with large scale storage. There are also other niche sectors, like long haul aviation, that may end up being the priority for use of renewably sourced hydrogen.

As an indicator of scale, a switch of the complete UK gas network to carry hydrogen would require the equivalent of twice the current global production of hydrogen (UK having approximately 1% of the global population).

There has been considerable interest in hybrid heat pumps that use hydrogen to cope with peak demands. However, a current research project shortly to be published by the IEA (International Energy Agency) Heat Pump Technologies TCP Annex 45 has identified that the product development has been largely curtailed because nations like Germany (where many of the potential manufacturers are based) have indicated, like the CCC, that renewable hydrogen may only be available for selective sectors. In addition, switching the gas grid to hydrogen would have a lower return on investment should it be used only for peak lopping capacity, and hence increase the relative cost of hydrogen as a building energy supply solution.

Consequently, this report takes the view that net zero carbon hydrogen is unlikely to be an option for heating the vast majority of new and existing buildings.

Further Reading:

→ "Hydrogen in a low carbon economy" Committee on Climate Change. *[Online]. Available from:* https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf

→ "Analysis of alternative UK heat decarbonisation pathways" Imperial College for the Committee on Climate Change. *[Online]. Available from:* https://www.theccc.org.uk/publication/analysis-of-alternative-uk-heat-decarbonisation-pathways/

A3.2: CO_2 refrigerant heat pumps

There is increasing interest and development going into heat pumps using CO_2 as a refrigerant (ASHRAE refrigerant designation number R-744). Besides having zero Ozone Depletion Potential (ODP), CO_2 also has an ultra-low Global Warming Potential (GWP) of 1 (unlike most currently used refrigerants, the most common of which typically have GWPs in the range of 1400 to 2100), is non-flammable (unlike almost all other natural refrigerants) and is non-toxic (unlike ammonia, which is often used as a refrigerant in large scale industrial applications). But perhaps of most interest in the context of Future Heat for buildings is the ability of CO_2 heat pumps to deliver domestic hot water (DHW) temperatures at relatively high efficiencies compared with most currently available heat pumps. Japan has been leading the research and product development of heat pumps suitable for buildings of a range of scales down to individual dwellings.

Existing heat pumps cannot be switched to CO_2 as a refrigerant: firstly, the system must be designed specifically for it, not least because it operates at significantly higher pressures than traditional heat pumps. Technically, this is fully solvable and, indeed, smaller bore pipework needed for smaller applications is inherently more pressure compatible. It is expected that all CO_2 refrigerant systems would be factory sealed so avoiding any site refrigerant pipework assembly.

Secondly, CO_2 heat pumps generally require large temperature differences in the fluid used to remove heat from the heat pump, whereas most other refrigerants can only deliver very modest fluid heat uplifts. This difference would normally require a significant reconfiguring of the building heat distribution system.

While not specifically referred to in this report, CO_2 heat pumps offer future technology potential, albeit initial performance claims may need to be qualified given the past performance gap between design expectations and operational performance for most current heat-pump systems.

Further Reading:

→ "Recent Advances in Transcritical CO_2 (R744) Heat Pump System: A Review" Rajib Uddin Rony, Huojun Yang, Sumathy Krishnan and Jongchul Song. *[Online]. Available from:* https://www.mdpi.com/1996-1073/12/3/457/pdf

A3.3: Reducing heat demand at point of use

Figure A.3.1 opposite shows indicative building design parameters expected to achieve the performance levels proposed for space heating and for domestic hot water (DHW). The same values are anticipated for most occupied building types, including offices and residential developments.

Indicative building design parameters

Heating: installed capacity of heating plant of 10 W/m² of floor area		
Roof & ground U-value	0.09 - 0.12 $W/m^2.K$	
Wall U-value	0.10 - 0.15 $W/m^2.K$	
Window & door U-value	1.0 $W/m^2.K$	Overall including frame
Window to wall ratio	<35%	Correlated with overheating avoidance & daylight
Envelope airtightness	<0.6	Air changes per hour @ 50Pa test pressure
Ventilation heat recovery	90%	For minimum fresh air during heating season only
Heat-pump control	24 hr enabled	Night setback to avoid morning boost grid demand
Domestic hot water: installed capacity of heating plant of 9 W/m²		
Low-demand outlets	EWL 'Green' rated	European rating (e.g.: shower 6 L/min)
Maximum dead-legs	Max 1 litre volume	Has increased significance with low demand
Smoothing demand	DHW storage	Individual dwelling with extended recovery
Smoothing demand	Community wide	Using diversity to meet installed capacity target
Commercial DHW	Use heat-pump	COP of 250% instead of 100% for direct-electric

Figure A3.1 - indicative building design parameters expected to achieve the performance levels proposed for space heating and for domestic hot water (DHW)

Notes:
→ EWL water outlet rating system http://www.europeanwaterlabel.eu/
→ Consider Heat Autonomy as an option for harnessing waste heat, reducing system costs, reducing standing losses and reducing grid peaks.
→ Consider 5th Generation heat-share ambient loop networks for harnessing waste heat (e.g.: heat rejection from cooling plant).

A3.4: Typical buildings

Indicative example measures for typical buildings

Heat measures for typical building types	Small scale residential	Medium scale residential	Large scale residential	Office	School
01. Enhanced envelope thermal performance	✓	✓	✓	✓	✓
02. Mechanical ventilation heat recovery	✓	✓	✓	✓	✓
03. 10 W/m² peak heating capacity	✓	✓	✓	✓	✓
04. 'Green' rated EWL hot water outlets	✓	✓	✓	✓	✓
05. DHW storage and trickle charge	✓	✓	✓	✓	✓
06. Exhaust air heat-pump	✓	✓	✓	✗	✗
07. In room water-source heat-pump	✗	✗	✗	✓	✓
08. Room exposed thermal mass to smooth peak demands	✓	✓	✓	✓	✓
09. Building heat-share water network	✗	✗	✗	✓	✓
10. Water source heat-pump connection to community heat-share network	✗	✓	✓	✓	✓
11. All-electric for access to grid renewables	✓	✓	✓	✓	✓
12. Roof area PV suffice for on-site net-zero-carbon	✓	✓	✗	✓	✓

Figure A3.2 - indicative example measure that can be used in typical buildings

Notes:

→ New EU water outlet rating system (EWL), e.g. certified 'Green' grade 6 litre per minute shower heads (without the use of flow restrictors).

→ EAHP using residual waste heat in extract ventilation after MVHR for supply both space heating top-up and DHW.

→ Room WSHPs providing heating (and cooling), both sourced from building wide heat sharing ambient loop network.

→ Room exposed thermal mass to smooth peak demands by ~25% for buildings with regular peak loads. Less data exists on benefits in average dwellings where users/systems tend to be more diverse.

→ Building heat sharing ambient loop water network operating at 15-25˚C allows redistribution and reuse of waste heat within building.

→ Connection to community wide heat sharing ambient loop network to allow any excess heat from cooling to be made available to other buildings – in particular, for difficult to upgrade residential with residual heating and DHW demand.

→ Fossil fuel free means that the heating system uses electricity, not gas or oil. This means that all residual energy can access grid renewables. The extent of this would need to be within a fair share of renewables capacity input into the grid and would need demand management to ensure demand periods are matched to grid renewables supply availability.

Small scale residential – terraced or semi-detached homes

→ Enhanced envelope thermal insulation and MVHR.
→ Maximum ~10 W/m² peak heat loss (including ventilation).
→ 'Green' EWL hot water outlets (e.g. certified 6 litre per minute shower heads, not using flow restrictors).
→ EAHP using residual waste heat in extract ventilation for both space heating top-up and DHW.
→ DHW storage trickle charged by EAHP.
→ All-electric [i].

Medium scale residential – up to 4 storeys

→ Enhanced envelope thermal insulation and MVHR.
→ Maximum ~10W/m² peak heat loss (including ventilation).
→ 'Green' EWL hot water outlets (e.g. certified 6 litre per minute shower heads, not using flow restrictors).
→ EAHP using residual waste heat in extract ventilation for both space heating top-up and DHW.
→ DHW storage trickle charged by EAHP
→ All-electric [i].

Large scale residential – more than 4 storeys

→ Enhanced envelope thermal insulation and MVHR.
→ Maximum ~10W/m² peak heat loss (including ventilation).
→ 'Green' EWL hot water outlets (e.g. certified 6 litre per minute shower heads, not using flow restrictors).
→ EAHP using residual waste heat in extract ventilation for both space heating top-up and DHW.
→ DHW storage trickle charged by EAHP
→ All-electric [i].

Commercial offices

→ Enhanced envelope thermal insulation with MVHR.
→ Maximum ~10W/m² peak heat loss (including ventilation).
→ 'Green' EWL hot water outlets (e.g. certified 6 litre per minute shower heads, not using flow restrictors).
→ Room WSHPs providing heating and cooling - both sourced from heat sharing network operating at 15-25°C. This allows redistribution and reuse of waste heat within the building.
→ All-electric building [i], using room exposed thermal mass to smooth peak demands by 25%.
→ Connection to community wide heat sharing network to allow any excess heat from cooling to be made available to other buildings – in particular, difficult-to-upgrade residential building stock with residual heating and DHW demand.

Schools – primary or secondary

→ Enhanced envelope thermal insulation with MVHR.
→ Maximum ~10W/m² peak heat loss (including ventilation).
→ 'Green' EWL hot water outlets (e.g. certified 6 litre per minute shower heads, not using flow restrictors).
→ Room WSHPs providing heating and cooling - both sourced from heat sharing network operating at 15-25°C. This allows redistribution and reuse of waste heat within the building.
→ All-electric building [i], using room exposed thermal mass to smooth peak demands by 25%.
→ Connection to community wide heat sharing network to allow any excess heat from cooling to be made available to other buildings – in particular, difficult-to-upgrade residential building stock with residual heating and DHW demand.

i - This means that the building does not burn fossil fuels on site. Heating and hot water can be generated by heat pumps. (It does not mean that direct electric is used for heating and hot water).

A4.1: Demand response and energy storage

Demand Response and energy flexibility can take place on any energy distribution network where a sizeable number of consumers and generators share the same network. Flexibility programs have mostly evolved alongside the incentives and markets that the National Grid and other bodies have created. Programs for emergency backup provision or reduction such as STOR (Short Term Operating Reserve) and FFR (Firm Frequency Response) have set the standards. Various companies have developed technology and systems in order to efficiently participate.

In general, the aim of all of these market systems is not to reduce carbon, but to balance demand and supply in the electrical network. In the future, energy markets will continue to evolve and have been increasingly accepting smaller amounts of energy flexibility for more specific applications.

Today, most participation in national energy flexibility initiatives can be grouped under the following categories:

→ Direct participation of large industrial consumers (e.g. steelworks, aluminium smelting)
→ Standalone energy storage projects (e.g. >1MW Battery Installations)
→ Aggregation of a large number of medium size flexible assets and storage (e.g. large chillers, pumps, small batteries)

Almost all participants today will use some form of remote control and electrical metering, usually referred to as an internet of things (IoT) device. These systems collect electrical data and can control a specific part of a system.

These IoT systems might directly control a device (such as setting the output of a battery inverter) or perhaps link into an existing BMS system. Electrical data is almost always collected to prove that an action has taken place and to monitor its progress. Naturally, this requires that electrical data is only collected from the flexible assets, so a good metering strategy is essential. There also tends to be a larger management system which collects the data, sends out the signals for when actions must take place and monitors ongoing actions.

A4.2: Direct carbon savings using a battery

Most demand response incentives are structured around system resiliency. However, let's explore the possibility of a purely carbon reduction focused flexibility scheme.

In carbon models today, fixed carbon intensity is commonly used for all electrical consumption in a building. Hour to hour, minute to minute, different generation sources are contributing to the overall supply on the electrical network. This means that the carbon intensity of the grid is always changing. See the Figure A4.1. This dynamic carbon intensity allows us to trade using it as a metric.

For example, we'll assume that we have a medium battery (100kW) and for comparison, we will compare three strategies:

→ Buy low, sell high, market exposed strategy (this may not be the highest money earning strategy)

→ Basic National Grid flexibility program, Dynamic FFR (this is the most common control strategy for a battery)

→ Buy low carbon, sell high carbon.

In general, participating in any form of energy flexibility program will be carbon positive (unless your flexible asset is some form of fossil fuel generation, then it would require further proof). At times when energy flexibility is required, participating assets tend to be replacing the output of fossil fuels like coal and gas. Notably, if using storage, this also means that the time you charge your storage will be as important as when you discharge it.

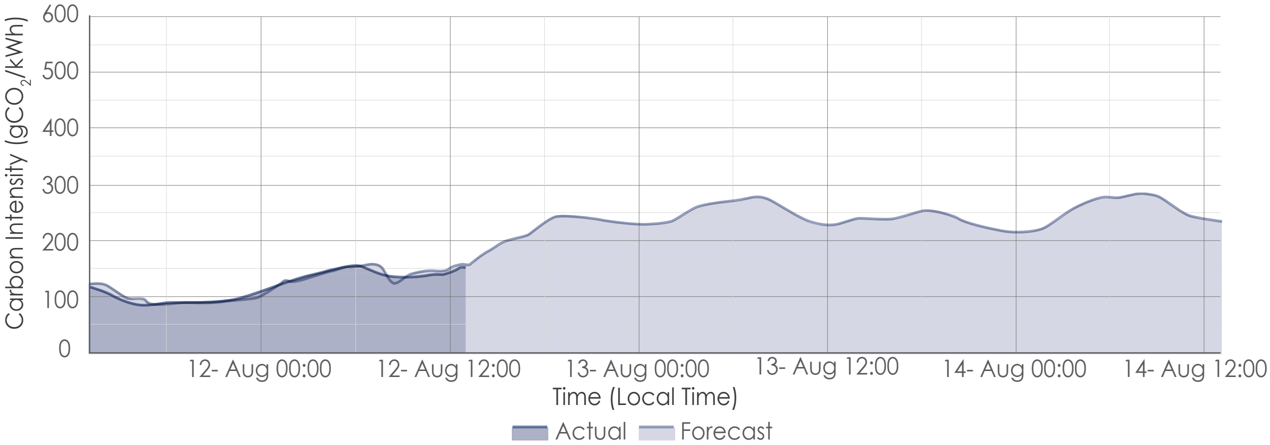

Figure A4.1 - Fluctuating carbon intensity (source https://carbonintensity.org.uk/)

A4.3: Theoretical stories of energy flexibility

Below are some examples of theoretical participants in energy flexibility initiatives.

Energy Manager
"I am an energy manager in charge of several schools. In order to reduce our energy bill, we started to participate in National Grid flexibility programs, agreeing to turn down our chillers at periods of grid stress. Now that the control and metering is in place, we have been able to better understand our energy use and have made further efficiency improvements. As part of a student led project, we will be using the improved control to turn off our chillers when coal plants are generating on the network, in order to reduce our carbon emissions."

Homeowner
"I am a semi-detached homeowner in London, recently my local authority created a phone app that can read my smart meter and gives me a score for avoiding using energy during peak periods. Depending on my score I can get points, which I can redeem for shopping vouchers! I've shifted my washing day to the weekend, and tend to put the heating on a bit later to help me get more points. I'm considering buying an electric car, and even though it will raise my electricity bill, apparently, I can set the charging time to 'only overnight' to gain even more points!"

A4.4: Metering requirements

Dedicated metering should be required for all flexible assets, this is an important part of proving that flexibility has taken place, and metering of a good standard is already a requirement of paid programs.

The level of metering required is tiered in that more complicated programs or larger pots have more stringent metering requirements, but generally have higher financial rewards. This should be considered when developing the metering strategy.

LETI would advise that you plan for the long term because metering requirements will get more stringent over time. Naturally, if the building is very small, or there is no intention to participate in a paid program due to restricted opportunities, then lower metering requirements could be justified.

Here are LETI's suggested general requirements, which are applicable to all systems regardless of size:

Metering should be appropriately sized for the building, whereby the least significant figure (LSF) of measurement is at the right level of accuracy.

- → Actual accuracy requirements depend on the program participation intended and are generally a percentage of maximum asset kW use. Future proofed design would be to get 1% overall accuracy, including all errors.
- → It should be possible to record data on a minute by minute basis.
- → Half hourly readings are a minimum requirement for some programs, but is not useful as it gives you very little information

about what the systems are doing at any specific moment in time.

→ Future proofed design would be able to record second by second metering, as markets seem to be moving in that direction.
→ At a minimum minute-by-minute readings should be recorded.

Regular data collection and storage should occur automatically, without human intervention, otherwise it will be forgotten about or will become expensive to record. Currently, flexibility aggregators use data collection hardware and software solutions to create a live data stream from the source, requesting data as soon as it is recorded.

Energy data should be securely stored, uneditable, and easily accessible by authorised users or systems.

→ This implies that a common data transmission standard and common data format should be used to ease integration with other systems or service providers that might be employed down the line.
→ Opening up data access or automatic communication to third parties or networks can be a cyber security risk. These risks can be managed, so appropriate steps should be taken to follow industry guidance on network and physical security to minimise potential risks.
→ Building occupants should be able to access their own data easily, as this can aid in self-directed energy efficiency activities.

Flexible assets can be grouped under one meter.

→ However, this could remove the ability to use different buildings in different flexibility programs.
→ It also removes the granularity of information that may be gained by knowing what each individual asset is doing.

Note: A problem has been identified in industry that some types of data collection, metering or control system are challenging to integrate with due to a lack of adherence to common standards. These systems have no place in an evolving forward looking development and should be avoided as they can cause large project costs when future work is being done - hence adhere to industry standard metering practices.

There are often further requirements for paid programs (such as accuracy and length of data retention) so please refer to the website and technical documentation of the paid program providers for further information, e.g. National Grid ESO.

A4.5 Reporting and Auditing

Once an energy flexibility system is in place, the auditing methodology can be quite straightforward:

→ Participation in formal paid energy flexibility programs
  → It can be assumed that a paid program will be well audited to begin with.
  → As participants are paid based on their response, the data should exist digitally. Therefore, it should be simple to extract data about the response.
→ If not taking part in a formal paid program, data based evidence should be provided to show that assets have been flexibly shifted to respond to external requirements, such as carbon saving. Gains, carbon based, financial or otherwise should be shown, as adherence to a constrained connection agreement.

The challenge is defining whether participation is either below standard or exemplary. It is not thought that responding only once a year is good enough. More frequent reporting of performance would be required.

Using a publicly published rating to rank buildings against each other would encourage the use of demand response systems.

For example, a school has saved 'X tonnes CO_2 per m^2 of floor space' this year, therefore, based on a bell-curve rating system against other schools, it gets a B+ rating. Alternatively, Office Y only utilised their battery once a month, therefore only get a D rating.

LETI would only recommend the implementation of binding targets for participation after a defined period of operation, after data is collected and comparisons can be made.

A5.1: Proposed energy reporting structure

Process flow diagram opposite showing information sources and key outputs recommended by LETI for energy disclosure.

Key principles for city wide energy disclosure:

1. The purpose is to improve building benchmarking and to provide transparency at a city level. It is not intended to allow diagnosis for individual buildings.
2. Simplicity should be prioritised over resolution of data. The data input by the applicant has been minimised and mirrors existing requirements as much as possible. API and data checking input should be used to improve data quality.
3. Voluntarily disclosure from non-referable or existing buildings should be encouraged. The data should be freely available to the industry and public.

Input by applicant

Input at completion of construction
Reported on whole building by applicant
Possible to input for existing buildings
For non-domestic buildings an annual DEC submission is sufficient to satisfy the majority of inputs.

Property information
→ Address
→ Date of assessment OR Issue date
→ Completion date
→ Certificate reference number
→ Building regulations version (dropdown)
→ Total floor area OR Total useful floor area
→ No. of flats
→ Building description and photo

Building categorisation
→ DEC Category OR Residential use category
→ (GRESB Category?)
→ Possible to select more than one
→ Gross internal floor area for each use*
→ Single defined building OR Multiple buildings across a site (how many?)

Annual displaced CO_2 emissions (offset)
→ From carbon offset fund contributions

Input within 14 months of completion
Annual updates by applicant for minimum of 5 years

Energy consumption
→ Over bespoke date range
→ Identify primary heating source
→ Metered electricity consumption (kWh)
→ Metered gas consumption** (m^3/kWh/cf)
→ Other fuel consumption** (m^3/kWh/cf)
→ Metered heat consumption for building (kWh) (required for district heating, optional for other buildings. Dropdown menu for heat network provider to give carbon factor)

Energy generation
→ Metered export generation over date range chosen, split between PV and other
→ Metered electricity generation (kWh)

From external source

Carbon content of fuel ($kgCO_2e/kWh$)
→ Conversion factors for greenhouse gases
→ Options for different value sets to be substituted in by viewer (not applicant) - default values set by GLA

Energy conversion factors
E.g. Volume to kWh
→ Calorific values

Cost of energy (£/kWh)
→ Ofgem reported figures

Calculated by platform

Annual consumption (kWh)
→ Electricity
→ Gas
→ Other fuel broken down by fuel type

Annual electricity generation (kWh)
→ Broken down between PV and other

Output by platform

Publicly disclosed for each building
Includes summary building information including area

Total energy consumption (kWh/m^2)
→ Broken down by building and fuel type

Total annual CO_2e emissions from building ($kgCO_2e/m^2$)
→ Broken down by building and fuel type

Total net CO_2e emissions from building ($kgCO_2e/m^2$)
→ Shown against offset contribution and emissions displaced at planning

Estimated energy cost per residential unit (£pa)

Total annual CO_2e emissions ($kgCO_2e$)
→ Imported electricity indirect emissions
→ Combusted fuel direct emissions e.g. gas burned on site
→ District heating system indirect emissions
→ Renewable electricity generated on site (PV)
→ Each per building for larger sites

Key

Information available from Energy Performance Certificate for all buildings

Information available from Display Energy Certificate (DEC) for buildings other than dwellings

* Information is only available in DEC full technical table report supplement. Additional requirement for mixed-use schemes

** Fuel and heat consumption are combined into one output on DEC

A6.1: Definitions

Air tightness: measures the infiltration of outdoor air into the building, or in other words how ‘leaky’ or ‘draughty’ the building is. A low energy building requires high levels of airtightness. Airtightness is measured in $m^3/h.m^2$ at a pressure of 50Pa (the pressure of the airtightness test). It can also be measured in air changes per hour through the external envelope. In either case, the lower the value the better.

Ambient loop: a heat sharing network at a low temperature that can be used to share heat between floors of buildings, or between different buildings. An ambient loop can be used to and make use of waste heat between buildings. E.g. an office building’s air conditioning system can reject heat an ambient loop, (rather than atmosphere), this heat can then be used by a neighbouring residential development.

Archetype: In the context of this document, one of four building typologies used as a means of modelling certain design criteria and targets to determine specific recommendations.

Biomass boiler: A form of direct combustion, heating and/or electricity derived from biomass (agricultural, forest, urban or industrial residues as opposed to fossil fuel).

Biofuel: Is a fuel that is produced through contemporary processes from biomass, not fossil fuel.

Biogenic carbon: Emissions are those that originate from biological sources such as plants, trees, and soil.

Bottom-up modelling: In the context of this document, using archetypes with varying key design parameters to determine realistically achievable EUIs and an ‘optimised’ design. Refer to page 47.

Carbon factor: It is the factor that is applied to electricity that is consumed by buildings, to understand that carbon emissions associated with the electricity use. The carbon factor of the UK grid changes throughout the day and the seasons depending on how much renewable energy is being generated.

Carbon sequestration: A natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form, e.g. reforestation or, in the built environment through using timber.

Circular economy: See page 25.

Combustion process: The chemical process of burning via a substance (fuel) reacting rapidly with oxygen and giving off heat.

Community renewables: a means of providing electricity via installations of renewable (e.g. solar panels, wind turbines) that are owned by, or have significant benefits for, residents and local organizations.

Cradle-to-cradle: Goes beyond ‘cradle to grave’ and conforms more to the model of the circular economy. In a cradle to cradle model products would be designed in a way so that at the end of their initial life they can be readily reused, or recycled, and therefore avoid landfill altogether. (source: www.circularecology.com)

Cradle-to-gate: A boundary condition associated with embodied carbon, carbon footprint and LCA studies. It considers all activities starting with the extraction of materials from the earth (the cradle), their transportation, refining, processing and fabrication activities until the material or product is ready to leave the factory gate. See also embodied energy. (source: www.circularecology.com)

Cradle-to-grave: A boundary condition associated with embodied carbon, carbon footprint and LCA studies. It includes the cradle to site results but also includes the GHG emissions associated with the in use of the material or product (maintenance) and the end of life (disposal, reuse, recycling). (source: www.circularecology.com).

Dead leg: The length of pipe to the outlet in a hot water system. When the outlet is not in use the hot water in this pipe loses its heat so when next used there is a time delay before fully hot water is again available at the outlet. This represents an inefficiency of the heat system.

Demand response: The ability of a system to reduce or increase energy consumption for a period of time in response to an external driver (e.g. energy price change, electricity grid availability). Refer to this document, Chapter 4.

District heating: Also known as a heat network, it is a system for distributing heat generated in a centralized location through a system of insulated pipes for residential and commercial heating requirements such as space heating and water heating.

Dynamic carbon factor: Variation in carbon emissions from the grid at different times of the day and year.

Electric vehicle turn-down: Charging electric vehicles only when needed and allowing the electricity supplier to stop charging the electric vehicles during peak electricity grid constraints. See this document p.94.

Embodied carbon (EC): See page 24.

Embodied energy (EE): See page 24.

Energy budget: A specific target for Energy Use Intensity (EUI) that LETI believe developments must not exceed in order to achieve net zero carbon, as demonstrated through archetypes. See also top-down modelling.

Energy flexibility assessment: The concept of recording the total kW of energy available that can be controlled and how long the consumption can be reduced, or energy stored for on a per building basis. See also this document Chapter 4.

Energy use intensity (EUI): See page 24.

Environmental Product Declaration (EPD): See page 56.

Feedback loop: In the context of this document, this describes communicating the disparity between design and operation. The lack of a feedback loop is the primary cause of the performance gap.

Firm Frequency Response (FFR): Allows a provider to provide a service whereby they may reduce the electricity consumption of a building or increase generation of electricity, when instructed by National Grid.

Form factor: a design parameter defined, for the purposes of LETI and operational energy, as the efficiency of the shape of a building.

Fossil fuel: A natural fuel such as petroleum, coal or gas, formed in the geological past from the remains of living organisms. The burning of fossil fuels by humans is the largest source of emissions of carbon dioxide, which is one of the greenhouse gases that allows radiative forcing and contributes to global warming.

Fuel poverty: A household is said to be in fuel poverty when its members cannot afford to keep adequately warm at a reasonable cost, given their income.

Geothermal: Heat derived within the sub-surface of the earth. Water and/or steam carry the geothermal energy to the Earth's surface. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity.

Glazing ratio: The proportion of glazing to opaque surface in a wall. Also called window-to-wall ratio, it is a key variable in façade design affecting energy performance in buildings.

Ground granulated blast-furnace slag (GGBS): A cement substitute in concrete applications.

Ground source heat pump (GSHP): A form of renewable heating or cooling system that transfers heat to or from the ground.

G-value: Sometimes also called a Solar Factor or Total Solar Energy Transmittance, it is the coefficient commonly used in Europe to measure the solar energy transmittance of windows.

Heat autonomy: Term used to describe a dwelling or other building that has self-sufficiency for heat and requires no heating system. This tends to mean sufficiently good building thermal performance to permit incidental room heat gains or similar sources to be recovered and upgraded to meet the residual heat demands.

Heat island effect: An urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. This can be caused be air conditioning systems, for example typical air conditioning systems remove heat from the building, transferring it to the air outside the building, this means that while air conditioning systems cooling the inside of the building they make the air outside the building hotter.

Heat pump: Heat pumps transfer heat from a lower temperature source to one of a higher temperature. This is the opposite of the natural flow of heat. Heat pumps can be used to provide space heating, cooling and hot water. A refrigerant fluid is run through the lower temperature source (ambient air, ground, water, etc.). The fluid 'absorbs' heat and boils, even at temperatures below 0°C (although the coefficient of performance (COP) decreases with lower temperature). The resulting gas is then compressed, which further increases its temperature. The gas is passed into heat exchanger coils, where it condenses, releasing its latent heat. The process then repeats. (Adapted from https://www.designingbuildings.co.uk/wiki/Heat_pump).

Heat sharing network: a network at a low temperature that can be used to share heat between floors of buildings, or between different buildings. E.g. an office building's air conditioning system can reject heat an ambient loop, (rather than atmosphere), this heat can then be used by a neighbouring residential development.

Incidental room heat gains: Heat gains to a room other than from the heating system. This could include heat gains from people, lighting, appliances and energy consuming equipment. It can also be from solar heat gain through glazing.

LETI Heat Decision Tree: Highlights the broad range of issues that the heating system selection must address, including; carbon emissions, avoiding higher energy bills, air quality issues, and countering future urban 'heat island' increases.. See this document p.80.

Life cycle assessment: See page 56.

Mechanical ventilation with heat recovery (MVHR): MVHR, heat recovery ventilation (HRV) or ventilation heat recovery (VHR) uses a heat exchanger to recover heat from extract air that would otherwise be rejected to the outside and uses this heat to pre-heat the 'fresh' supply air. (https://www.designingbuildings.co.uk/wiki/Thermal_bridging_in_buildings) As a result, MVHR is more energy efficient than natural ventilation, whilst also providing air quality and acoustics benefits.

Microgrid: A key component contributing to demand response and energy storage. A small semi-isolated energy network that allows the development to operate as an 'energy island', essentially cutting itself off from national energy networks if needs arise. See this document p.96.

Net zero operational carbon: A new building that achieves a level of energy performance in-use in line with our national climate change targets that does not burn fossil fuels and that is 100% powered by renewable energy.

Offsetting: Offsetting is the process of compensating for the remaining carbon emissions balance by contributing, usually financially, towards solutions to reduce emissions elsewhere. Typically, this is put in practice by establishing carbon offset funds which then invest in renewable energy and other carbon reduction measures. See Appendix 10 of the LETI Embodied Carbon Primer for more information.

Open source data: Data that is publicly available, that is released in a specific way to allow the public to access it without having to pay fees or be unfairly restricted in its use.

Operational carbon (kgCO_2e): See page 24.

Passive heat demand reduction: Reduction in heat demands before consideration of the (active) systems used to deliver the heat. Sometimes called 'point of use' heat demands. For space heating this would include improving the building envelope and reducing the infiltration of outdoor air.

Peak demand: Refers to the times of day when our electricity consumption is at its highest which, in the UK, occurs between 5-30pm to 6pm each weekday evening.

Performance gap: This term refers to the discrepancy between energy predictions at design stage, compared to in-use energy consumption of buildings.

Post-occupancy evaluation (POE): Post-occupancy evaluation is the process of obtaining feedback on a building's performance in use after it has been built and occupied. By accurately measuring factors such as building use, energy consumption, maintenance costs and user satisfaction, POE allows for a process of continuous improvement in the construction industry.(Source: https://www.architecture.com/-/media/gathercontent/post-occupancy-evaluation/additional-documents/ribapoebpeprimerpdf.pdf)

Primary energy: See page 25.

Regulated energy: See page 24.

Renewable energy: Renewable energy technologies use natural energy sources to generate electricity and/or heating/cooling. Sources include solar, wind, wave, marine, hydro, etc..

Soft Landings Framework: The term soft landings refers to a strategy designed to make an easy transition from the construction to occupation phases of a project with the overriding aim of realising optimal operational performance. It's all about narrowing the performance gap between design intent and operational outcomes that can emerge at any stage in a construction project. (source: www.thenbs.com)

Solar thermal: Is a renewable form of energy and a technology for harnessing solar energy to generate thermal energy. Devices are often roof mounted to absorb the sun's heat and use it to heat up water, stored in a cylinder.

Thermal bridge: Heat makes its way from the heated space towards the outside. In doing so, it follows the path of least resistance. A thermal bridge is a localised area of the building envelope where the heat flow is different (usually increased) in comparison with adjacent areas (if there is a difference in temperature between the inside and the outside). (https://www.passipedia.org/basics/building _ physics _ - _ basics/thermal _ b ridges/thermal_bridge_definition).

Thermal mass: A property of the a material in a building which enables it to store heat, providing "inertia" against temperature fluctuations. It will absorb thermal energy when the surroundings are higher in temperature than the mass, and give thermal energy back when the surroundings are cooler.

Thermal storage: Thermal energy storage is achieved with widely differing technologies. It allows excess thermal energy to be stored and used hours, days, months later. In the context of this document, it is usually refers to hot water stores in buildings.

Top-down modelling: In the context of this document, the setting of EUI "ceilings" for building archetypes based on forecasts for available renewable energy generation in the UK to the average total floor area. Refer to this document to p.47.

Upfront embodied carbon: See page 24.

Unregulated energy: See page 24.

Upfront emissions: The embodied carbon associated with building construction, including the extraction and processing of materials and the energy and water consumption in the production, assembly, and construction of the building. This is distinct from "in-use" and "end of life" stages.

Urban heat island: see 'heat island effect'

U-Value: the rate of transfer of heat through a structure (which can be a single material or a composite), divided by the difference in temperature across that structure. The units of measurement are W/m^2K.

Vehicle to grid: This reverse charging EV technology allows the battery of the EV to be used to supply the building. See this document p.49.

Waste water heat recovery system: Works by extracting the heat from the water a shower or bath sends down the drain. This heat is used to warm the incoming mains water, reducing the energy required to heat the water up.

Whole life carbon (WLC): See page 25.

Zero carbon balance: A building that achieves a zero carbon balance is 100% powered by renewable energy, achieves a level of energy performance in-use in line with our national climate change targets and does not burn fossil fuel.

A7.1: Abbreviations

A/C	Air Conditioning
AHU	Air Handling Unit
APF	Assured Performance Framework
ASHP	Air-source heat-pump
BBP	Better Buildings Partnership
BIM	Building Information Modelling
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
BUS	Building Use Studies
CCC	Committee on Climate Change
CCS	Carbon Capture and Storage
CHP	Combined heat and power unit (usually gas-fired)
CIBSE	Chartered Institution of Building Services Engineers
CLT	Cross Laminated Timber
CO_2	Carbon Dioxide
COP	Coefficient of performance
DEC	Display Energy Certificate
DfMA	Design for Manufacture and Assembly
DHW	Domestic hot water
DNO	Distribution Network Operator
DX	Refrigerant piped between split units (often reverse-cycle)
EAHP	Exhaust-air-source heat-pump
EAM	Environmental Assessment Method
EC	Embodied Carbon
EoL	End of Life
FSC	Forest Stewardship Council
GGBS	Ground Granulated Blast-furnace Slag
GHG	Greenhouse Gases
GIA	Gross Internal Area
GLA	Greater London Authority
GWP	Global Warming Potential
HVAC	Heating , Ventilation and Air Conditioning
IEA	International Energy Agency
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
LBSM	London Building Stock Mode
LCA	Life Cycle Assessment
LETI	London Energy Transformation Initiative
MEV	Mechanical Extract Ventilation
MEP	Mechanical, Electrical and Public health
MVHR	Mechanical Ventilation with Heat Recovery
NABERS	National Australian Built Environment Rating System
NBS	National Building Specification
NRM	New Rules of Measurements
PFA	Pulverised Fuel Ash
PH	Passivhaus
PHPP	Passivhaus Planning Package
POE	Post Occupancy Evaluation
RIBA	Royal Institute of British Architects
RICS	Royal Institute of Chartered Surveyors
SCoP	Seasonal Coefficient of Performance
SEER	Seasonal Energy Efficiency Rating
SFP	Specific Fan Power
UHI	Urban Heat Island
UKGBC	United Kingdom Green Building Council
VRV	Variable Refrigerant Volume
WGBC	World Green Building Council
WSHP	Water source heat pump
WLC	Whole life carbon
ZC	Zero carbon

A8.1: Acknowledgements

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This is a climate emergency

We are in a climate emergency, and urgently need to reduce carbon emissions. Here in the UK, 49% of annual carbon emissions are attributable to buildings. Over the next 40 years, the world is expected to build 230 billion square metres of new construction – adding the equivalent of Paris to the planet every single week – so we must act now to meet the challenge of building net zero developments.

The London Energy Transformation Initiative have developed this Climate Emergency Design Guide to provide practical solutions for the built environment - setting out a definitive journey, beyond climate emergency declarations, into a net zero carbon future.

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