1. Design Guidance for Net Zero

Guidance for applicants on how to design to achieve Net Zero Carbon buildings

March 2025

GMCA GREATER MANCHESTER COMBINED AUTHORITY

Etude

Levitt Bernstein People.Design

Net Zero guidance – A suite of three guides

This document is part of a suite of three Net Zero guidance documents prepared by the Greater Manchester Combined Authority, Levitt Bernstein and Etude.

'Design Guidance for Net Zero' focuses on how to design buildings to achieve the net zero ambitions and outcomes set in GMCA policy.

Although it can be read independently from the other documents, the reader may find it useful to refer to all three parts as they provide additional guidance.

Three key guidance documents:

1 Design guidance for Net Zero

Design considerations to meet policy JP-S2 and TANZ net zero standard, and linked to JP-S3.

- Definition of Net Zero
- Net Zero operational carbon design (2)
- Designing for low embodied carbon
- Case studies
- Signposts to industry guidance

2 Low carbon heat

Design considerations to meet policy JP-S3, linked to JP-S2.

- Heating systems for Net Zero (1)
- Examples of low carbon heating solutions
- Heat network opportunity areas/zones
- How to assess heating systems
- Required justification for non-connection

3 Submission guidance

Planning submission guidance influenced by JP-S2, JP-S3 and linked to TANZ.

- Submission requirements – Energy and Carbon Proforma and Energy and Carbon Statements
- Content of energy and carbon statements (1) (2)
- Calculations and results guidance
- Approved compliance routes

Energy and Carbon Proforma

Contents

Interactive navigation

To move through this guide with ease, use the interactive buttons in the top right hand corner of each page. A return to contents button is also available should you lose your way.

Explainer

Guidance context

The *Design Guidance for Net Zero* is the first of a set of three documents:

1. Design guidance for Net Zero
2. Low carbon heat
3. Submission guidance

The purpose of this guidance

The purpose of the *Design guidance for Net Zero* document is to explain how design can influence the Net Zero Carbon outcomes of a building. This document explains the relevant strategies to design Net Zero buildings, in line with GMCA policies in a user friendly and illustrated document.

While construction specifications can be improved to meet Net Zero, this comes at a capital cost premium, therefore, it is more effective to ensure design measures such as orientation, compact building forms, and window areas at an early design stage.

Links to other documents

Guidance on low carbon heat will be summarised in this document and links to more detailed information in guidance document Low carbon heat. 2

Who this guidance is aimed at

This guide is primarily aimed at applicants for full or outline planning permission, to influence the early design of buildings to meet Net Zero Carbon policy. The design concepts in this guidance are relevant for anyone designing a Net Zero building.

How this guidance relates to GMCA policies

The *Net Zero design guidance* focuses on policy JP-S2 sections (2) and (5), as well as linking to Truly Affordable Net Zero (TANZ) requirements.

A short summary of JP-S3 design strategies has been included in this document. However, technical detail and further information can be found in the *Low carbon heat* document.

Policies covered by the suite of documents:

JP-S2 – Carbon and Energy

- (2) Use of lifecycle carbon tools
- (5) Net Zero operational carbon – meeting set targets and following the energy hierarchy:
    - Minimise energy demand;
    - Maximise energy efficiency;
    - Use renewable energy;
    - Use low carbon energy; and
    - Utilise other energy sources.

JP-S3 – Low Carbon Heat

- (2) Expectation for connection in the 'Heat and Energy Network Opportunity Areas'

Truly Affordable Net Zero (TANZ)

- Link the requirements of TANZ with planning policy

1

Definition of Net Zero

Greater Manchester climate commitments

Global climate emergency

There is overwhelming scientific consensus that climate change is happening. As such, Greater Manchester is committed in making a fair contribution to international commitments by becoming a carbon neutral city region by 2038. To support this, the Greater Manchester Combined Authority (GMCA) declared a climate emergency in 2019.

Places for Everyone (PfE)

In March 2024, the Places for Everyone (PfE) plan prepared by GMCA took effect and became part of the statutory development plan for nine local authorities (Bolton, Bury, Manchester, Oldham, Rochdale, Salford, Tameside, Trafford and Wigan). PfE is a long-term development plan for jobs, new homes, and sustainable growth covering the Greater Manchester area.

Climate change has been a key theme of the PfE plan, in particular through the introduction of the following policies:

- **Policy JP-S2 'Carbon and Energy** referring to the zero carbon new and existing development, effective land management and through the provision of infrastructure and new technologies.
- **Policy JP-S3 'Heat and Energy Networks'** which refers to the delivery of low carbon heating.

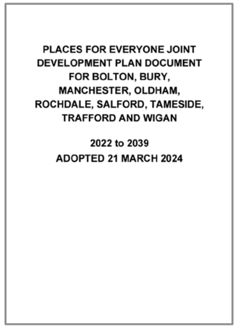
Through policy JP-S2, the plan sets out a pathway for new development to be Net Zero Carbon by 2028 at the latest, to support the Greater Manchester ambition to be a carbon neutral city-region by 2038.

Truly Affordable Net Zero Homes (TANZ) standard

In 2021 a new Net Zero commitment was also adopted by GMCA, to support the manifesto commitment made by the Mayor of Greater Manchester. A commitment was made to build 30,000 Net Zero social rented homes across the city region by 2038. As a consequence, the proposed TANZ standard was adopted 2023. The TANZ standard will apply to any new build social housing delivered by local authorities or other housing providers in Greater Manchester.

Guidance to meet policy

This suite of guidance documents aims to provide applicants with enough information to comply with Part 2 and 5 of the JP-S2 policy and Part 2 of the JP-S3 policy. They also cross reference the TANZ homes standard.



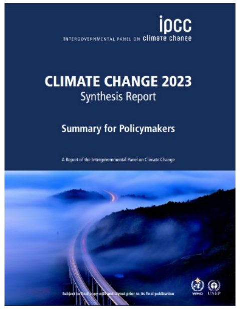
PLACES FOR EVERYONE JOINT DEVELOPMENT PLAN DOCUMENT FOR BOLTON, BURY, MANCHESTER, OLDHAM, ROCHDALE, SALFORD, TAMESIDE, TRAFFORD AND WIGAN

2022 to 2039

ADOPTED 21 MARCH 2024

Places for Everyone plan – 2024

'Our ambitions to be carbon neutral by 2038 have never been more necessary – we need to support the creation of resilient, liveable places where walking and cycling are the obvious choice for shorter journeys, where facilities and services are accessible and close at hand and where the past dependency on the car is superseded by a reliable and responsive public transport system.'



As part of GMCA's declaration, the findings of the IPCC Synthesis Report-2023 are referenced, which summarises five years of reports on global temperature rises, fossil fuel emissions and climate impacts. The report highlights that to keep within the 1.5°C limit, global emissions need to be reduced by at least 43% by 2030 compared to 2019 levels, and at least 60% by 2035. Therefore, this is the decisive decade to make that happen.

Net Zero Carbon new buildings in Greater Manchester

Places for Everyone (PfE) Net Zero definition

The definition of Net Zero Carbon development being used in PfE references the UK Green Building Council (UKGBC) framework definition. PfE policy JP-S2 states that:

"Buildings should be Net Zero Carbon, which applies:

- *from adoption (March 2024)– to regulated operational carbon emissions;*
- *from 2025 – to calculate and minimise carbon emissions from unregulated emissions alongside regulated emissions'*
- *from 2028 - to all emissions 'in construction'* [including upfront embodied carbon emissions]."

The UKGBC definition of Net Zero was later further developed with the Low Energy Transformation Initiative (LETI). The Net Zero Operational Carbon One-pager outlines a set of metrics and targets to achieve Net Zero Carbon by 2030 for all new buildings. LETI have also set target levels for upfront embodied carbon, as well as balancing energy use with on-site renewable energy generation to deliver Net Zero Carbon in practice.

The TANZ homes requirement aligns with the LETI and UKGBC energy use intensity target of 35 kWh/m^2/yr.

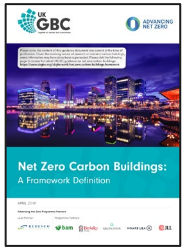
PfE Net Zero requirements

For applicants to comply with JP-S2, JP-S3 policy and the TANZ homes standard, all new buildings should be designed and built to be Net Zero Carbon in operation. They should comply with the following **GMCA Net Zero operational** requirements:

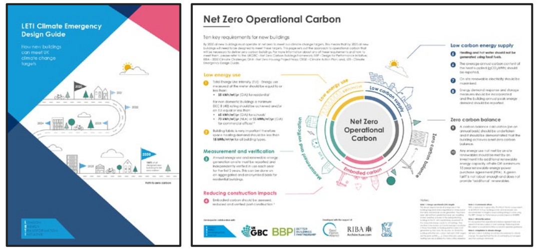
1. Fabric efficiency requirement
2. Energy use and carbon emissions
3. Energy Use Intensity (EUI)
4. No fossil fuels and low carbon heat
5. On-site renewable energy generation and energy balance
6. Offsetting (as last resort)

Additional GMCA policy requirements include:

1. Upfront embodied carbon reporting
2. Overheating risk reduction
3. Reporting energy consumption in-use



UKGBC Net Zero definition (2019)

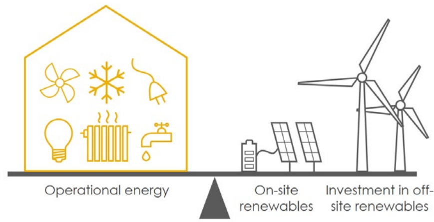


LETI Net Zero Definition- (backed by UKGBC) (2020)

Net zero carbon – operational energy

"When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."

Net Zero Carbon in operational

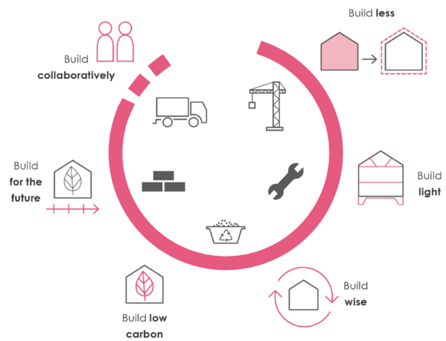


Operational energy balance

Net zero carbon – construction

"When the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy."

Net Zero Carbon in construction



Embodied carbon cycle

Places for Everyone energy hierarchy

Energy Hierarchy

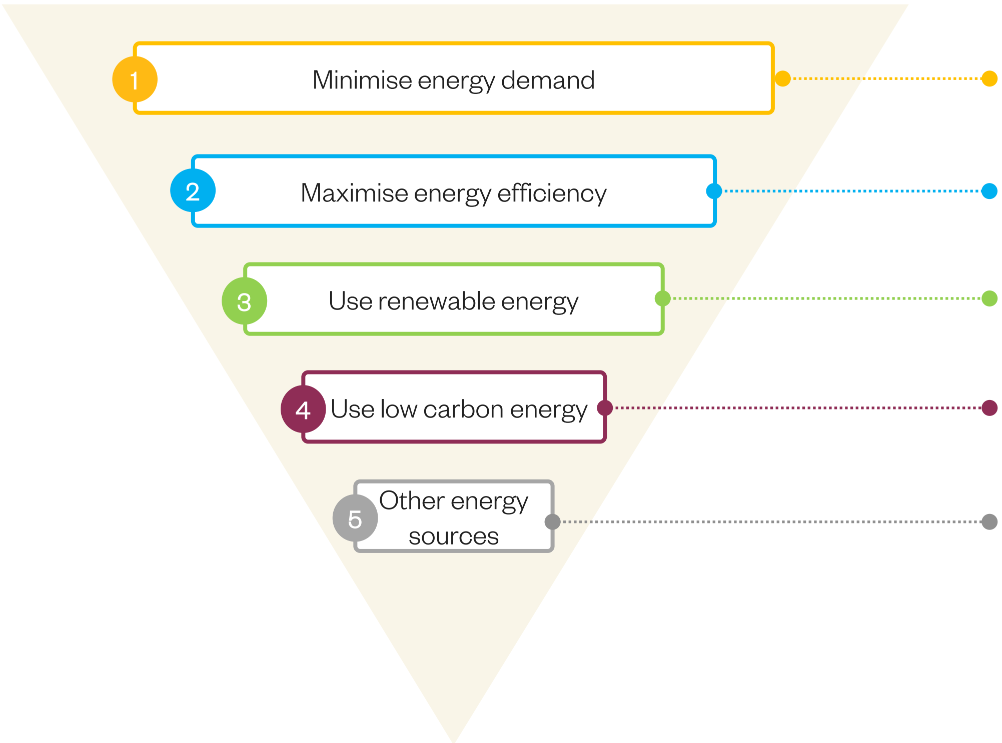
Places for Everyone has a defined Energy Hierarchy in policy JP-S2 Carbon and Energy, section 5. It sets out the order of importance for reducing total operational energy.

Links to the Energy and Carbon Framework

This energy hierarchy has formed the basis for the Energy and Carbon Framework, which sets out the principles of a Net Zero Carbon building. The Energy and Carbon Framework is described on the following page.

Metrics and key performance indicators

'Submission Guidance' in document 3 sets out the metrics and key performance indicators that apply with each step of the hierarchy. Supplementary metrics have also been developed to cover all the principles of a Net Zero Carbon building. Compliance with these key performance indicators can be demonstrated through the submission of an Energy and Carbon Proforma.



Minimise energy demand - use less energy during operation, through design strategies such as energy efficient fabric and ventilation.

Maximise energy efficiency – consider the total operational energy use of buildings, and use energy efficiently through use of low carbon heating systems.

Use renewable energy - maximise opportunities for renewable energy, by generating, and using renewable energy on-site.

Use low carbon energy - maximise use of clean, low carbon energy, avoiding the use of fossil fuels.

Other energy sources - when all the above steps have been taken.

Energy and Carbon Framework

Principles of a Net Zero Carbon building:

1 Minimise energy demand

Space heating demand (kWh/m^2_{GIA}/yr)

The building must achieve the space heating demand limits through energy efficient fabric and ventilation.

2 Maximise energy efficiency

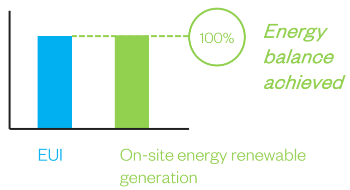
Energy Use Intensity (EUI) (kWh/m^2GIA/yr)

The building should meet the total energy use (regulated and unregulated), through low carbon and energy efficient heating systems. TANZ homes must meet an EUI limit.

3 Use renewable energy

PV footprint area (%)

The building should seek to maximise the generation of on-site renewable energy . There should be a balance between predicted annual energy use and annual renewable energy generation.



4 Use low carbon energy

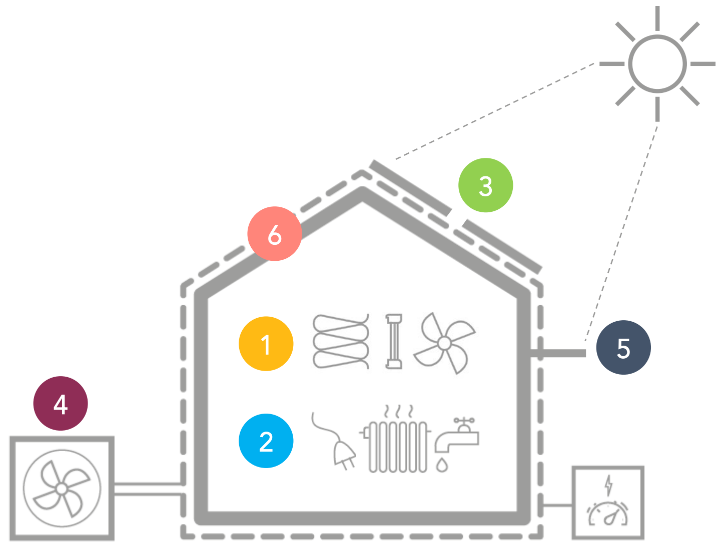
Fossil fuel free (yes/ no)

The building must not connect to the gas network or, more generally, use fossil fuels through a heat network. Low carbon heating systems must be installed.

5 Reduce overheating risk

Risk assessment/ full overheating assessment (pass/fail)

The building must assess the risk of overheating and minimise it through window design and shading strategies. Mechanical cooling in residential developments should only be installed when justified.



6 Minimise embodied carbon

Upfront embodied carbon (kgCO_2e/m^2GIA)

Embodied carbon should be minimised through efficient design and low carbon material selection. The building should meet the upfront embodied carbon benchmarks and the highest carbon materials used should be reported.

7 Offsets

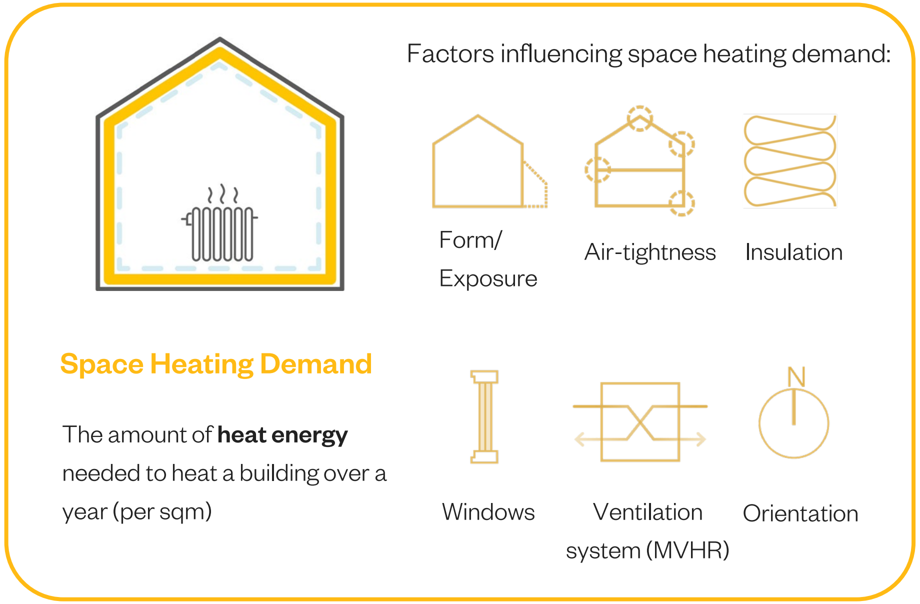
Financial offset contribution

Following the implementation of steps 1 -6, financial contributions are the last step to offset the remaining emissions/energy. The decision to include offsetting will be determined by each local authority in Greater Manchester, with options for offsetting currently under development.

Space heating demand and energy use intensity - explained

Space Heating Demand (SHD)

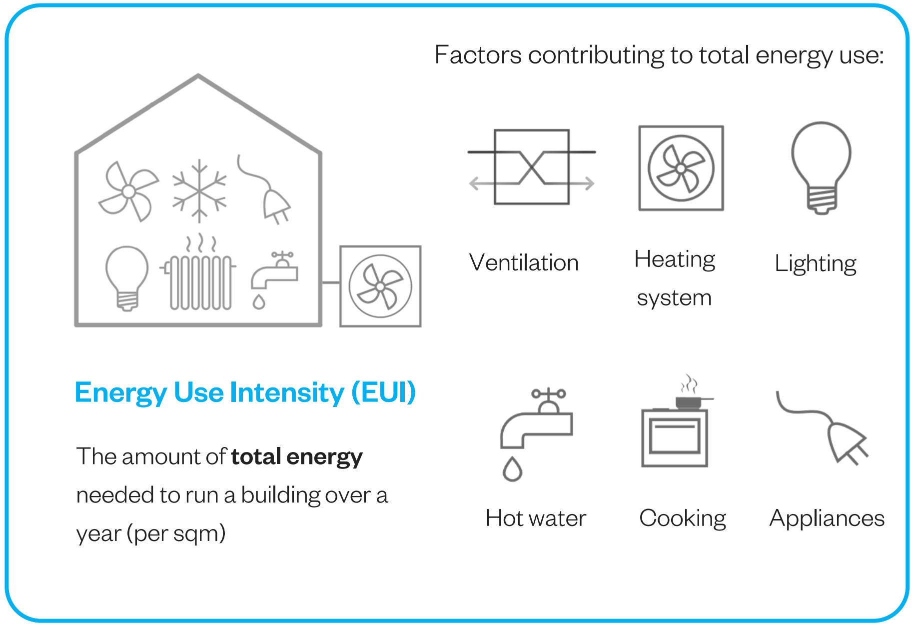
Various design and specification decisions affect space heating demand including building form and orientation, insulation, air-tightness, windows and doors and the type of ventilation system. The 2025 PfE JP-S2 policy requirement aligns with the Climate Change Committee recommendation of a space heating demand of less than 15-20 kWh/m^2/yr for new homes.



Energy Use Intensity (EUI)

For new homes to be compliant with Greater Manchester Truly Affordable Net Zero homes (TANZ) targets, they need to use a total amount of energy, calculated on an annual basis, which is small enough that it meets the UK's climate commitments. The EUI metric is very beneficial as it can be measured post-construction, therefore helping to reduce the performance gap which is a significant issue in the construction industry.

The TANZ policy requirement is to achieve an EUI of less than 35kWh/m^{2}GIA/yr.



Energy Use Intensity (EUI) - a simple, measurable metric

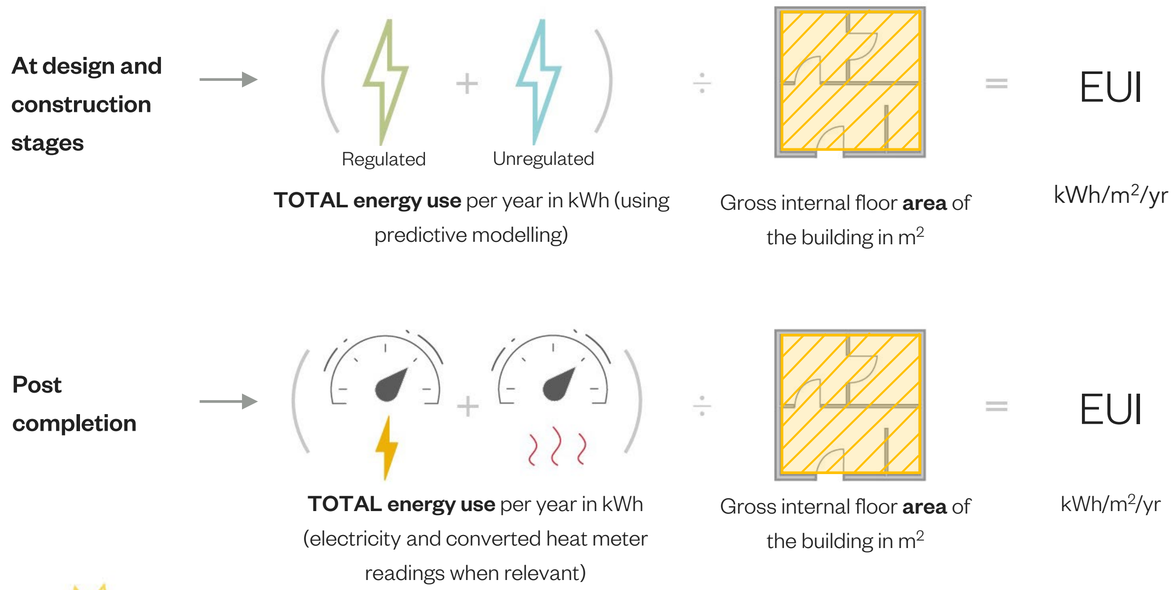
What is the EUI?

The Energy Use Intensity (EUI) represents the total amount of energy used by a building divided by its floor area (GIA). This includes any spaces within the thermal line of the building, such as: living and dining, bedrooms and communal/circulation spaces. It is reported in kWh/m²/year. It is based on delivered energy and does not need to be converted in primary energy using any factors.

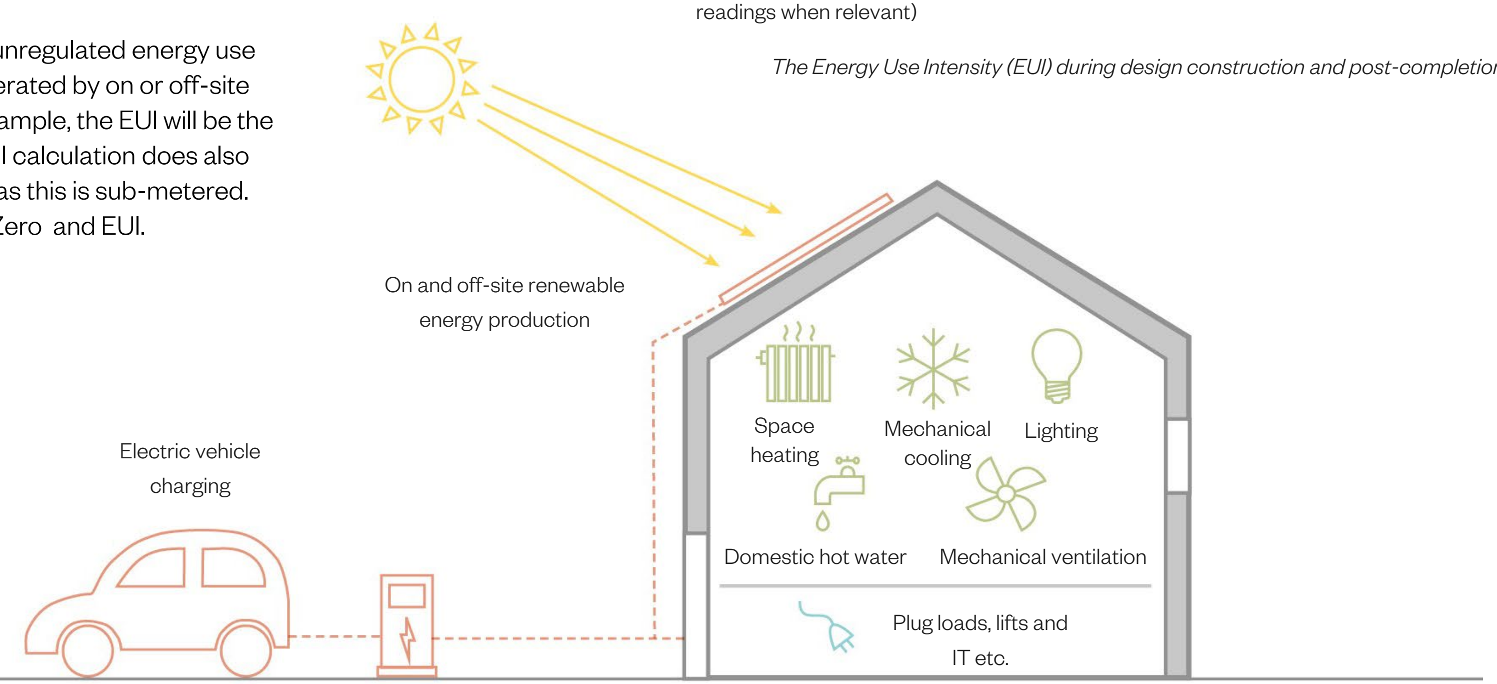
The EUI is a good indicator of the energy efficiency of a home/building and can be calculated or checked at both design stage and post completion. For homes/buildings heated by an individual heating system, it is very easy for the occupant/resident to check post-completion as it will be the annual 'energy at the meter' divided by the floor area. For communally heated dwellings/buildings, heat 'at the meter' will need to be converted to heat energy.

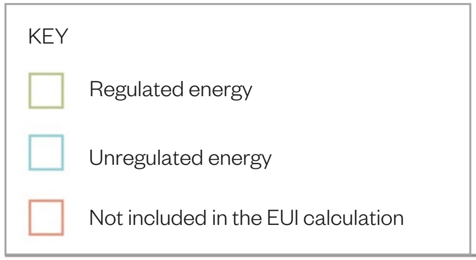
What is included in the EUI?

EUI includes both the regulated energy use and unregulated energy use from homes and communal spaces. Energy generated by on or off-site renewables does not affect the EUI value. For example, the EUI will be the same whether the building has PV or not. The EUI calculation does also not include charging of electric vehicles, as long as this is sub-metered. For further detail refer to LETI guidance on Net Zero and EUI.



The Energy Use Intensity (EUI) during design construction and post-completion





What is included in the EUI?

Note: EUI should not be confused with Primary Energy which relies on the multiplication of energy use by primary energy factors specific to each fuel (similarly to carbon emissions which rely on the multiplication of energy use by carbon factors.

Embodied carbon - explained

The making of materials, their transport, repair and deconstruction affects how much carbon is associated with them. Embodied carbon is assessed through the use of different boundaries. This is a summary of the key boundaries and the terms associated with them.

Upfront and lifecycle embodied carbon is measured in tonnes (tCO_2e) and is normalised to $kgCO_2e/m^2$. For example, if the volume of concrete in one building is the same as that of another, they will emit the same total tCo_2e. However, if one building is twice the floor area of the other, when normalised, it will become obvious that the smaller building has higher emissions per m^2 GIA ($kgCO_2e/m^2$).

Upfront embodied carbon

Upfront embodied carbon refers to the greenhouse gas emissions associated with material and construction stages: raw material supply, manufacture, transport and construction of all building elements

Life cycle embodied carbon

Life cycle embodied carbon includes both upfront embodied carbon and the embodied carbon associated with:

- In-use - maintenance, replacement and refrigerant leakage.
- End of life - waste processing of demolition/deconstruction and disposal of any products.

Operational carbon

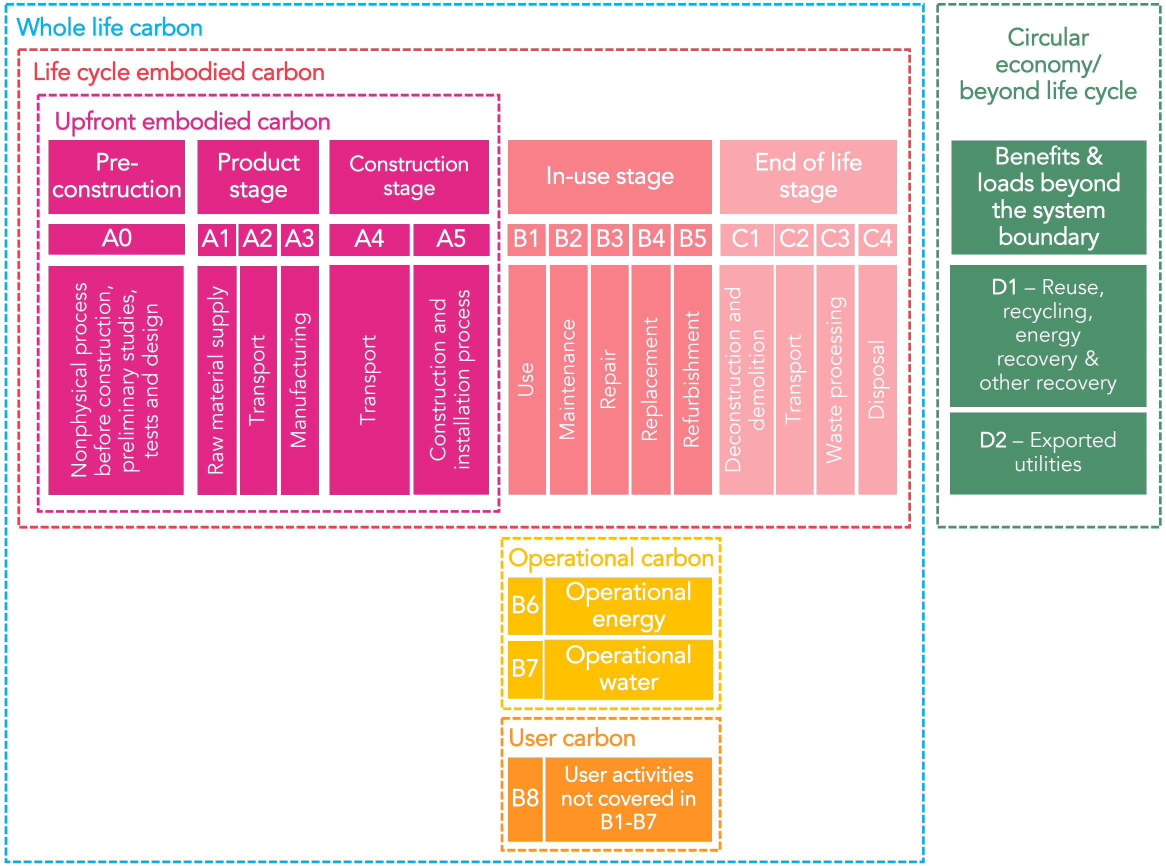
Operation carbon refers to the emissions associated with energy and water use during operation.

User carbon

User carbon covers the emissions from user activities, outside of the use of energy and water emissions from the operation of the building. An example includes transport or vehicle charging. This module is typically outside the remit of building design and has not been included on following pages.

Whole life carbon (WLC)

For buildings, whole life carbon is the sum of life cycle embodied carbon and operational carbon.



Modular information for the different boundaries of the building assessment. *This version of the diagram is adapted from a combination of the diagram from the BS EN 15978, RICS 2023 and LETI.*

Circular economy/beyond life cycle

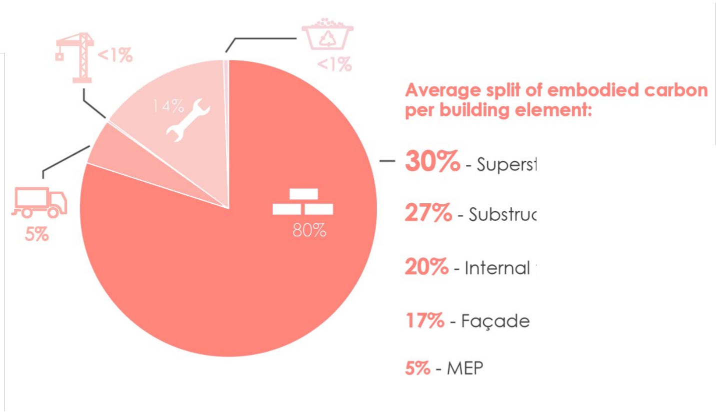
A circular economy seeks to ensure materials can be re-used again and again and are ultimately diverted from landfill or incineration. This builds on embodied carbon principles, such as material re-use, recovery and recycling.

Measuring upfront embodied carbon – materials and quantities

Upfront embodied carbon associated with one particular material is calculated by multiplying its embodied carbon rate by its quantity.

Materials used in superstructure and substructure are generally used in large quantities, so their selection is likely to have a significant impact on the overall upfront embodied carbon.

Using a high embodied carbon material may be acceptable if it is used in small quantities. If used in large quantities, lower carbon alternatives should be investigated.



Products/materials (A1-A3)

Transport (A4)

Construction (A5)

Maintenance and replacements (B1-B5)

End of life disposal (C1-C4)

Reducing embodied carbon for the largest uses/ greatest quantities *(Source: LETI)*

These are Danish figures and are not intended to be used in the UK, but the hierarchy is useful ***as an illustration****. The material selection pyramid illustrates high embodied carbon materials at the top and low embodied carbon materials at the bottom (module A1-A3, based on global warming potential). Follow link* *www.materialepyramiden.dk* *to see the pyramid in more detail.*

2

Energy and carbon requirements

Residential - Metrics and key performance indicators

The success of Net Zero Carbon design and construction is measured in policy JP-S2 through a series of metrics and key performance indicators (KPIs). These metrics and KPIs provide an indication of how the design has influenced the performance of the building.

This page lists the residential KPIs. The following sections provide guidance on how design can result in improved performance against the key performance indicators.

See Submission guidance in document 3 for definitions of minor and major development.

	Minor development		Major development	
	Small minor Single home and XL extensions	**Minor** 2-9 homes	**Major** 10-149 homes	**Large major** +150 homes
Space heating demand (kWh/m$^2_{GIA}$/yr) *Minimise energy demand*	Specs (Space heating demand)	≤ 20 kWh/m².yr (Space heating demand - HOUSES); ≤ 15 kWh/m².yr (Space heating demand - FLATS)	≤ 20 kWh/m².yr (Space heating demand - HOUSES); ≤ 15 kWh/m².yr (Space heating demand - FLATS)	
Energy Use Intensity (EUI) (kWh/m2GIA/yr) *Maximise energy efficiency*	*Not applicable (35kWh/m²/yr for all TANZ homes)*	≤ 35 kWh/m².yr (Energy use intensity) *Requirement for all TANZ homes*	≤ 35 kWh/m².yr (Energy use intensity) *Requirement for all TANZ homes*	
PV footprint area (% of ground floor space) *Use renewable energy*	≥ 40 % fp (PVs installed)	≥ 40 % fp (PVs installed)	≥ 40 % fp (PVs installed)	
Fossil fuel free (yes/ no) *Use low carbon energy*	Yes (Fossil fuel free)	Yes (Fossil fuel free)	Yes (Fossil fuel free)	
Building regulations Part O met without mechanical cooling (yes/no) *Reduce overheating risk*	GHA (Overheating risk assessment tool)	Yes (Cooling avoided)	Yes (Cooling avoided)	
Upfront embodied carbon (kgCO_2e/m$^2_{GIA}$) *Minimise embodied carbon*	Summary of efforts (Upfront embodied carbon)	Summary of efforts (Upfront embodied carbon)	≤500 kgCO_2/m² (Upfront embodied carbon - HOUSES); ≤600 kgCO_2/m² (Upfront embodied carbon - FLATS)	
Offset contribution (£) *Offsets*	*Not applicable*	*Not applicable*	£ (Offsets) *Options for offsetting currently under development and to be adopted by each local authority.*	

Non-residential - Metrics and key performance indicators

The success of Net Zero Carbon design is measured in policy JP-S2 through a series of metrics and key performance indicators (KPIs). These metrics and KPIs provide an indication of how the design has influenced the performance of the building.

This page lists the non-residential KPIs. The following sections provide guidance on how design can result in improved performance against the key performance indicators. See Submission guidance in document 3 for definitions of minor and major development.

	Minor development		Major development	
	Small minor <100m^2	**Minor** 100-999m^2	**Major** 1,000-4,999m^2	**Large major** +5,000m^2
Space heating and cooling demand (kWh/m$^2_{GIA}$/yr) *Minimise energy demand*	Specs (Space heating demand)	≤ 15 kWh/m^2.yr (Space heating demand)	≤ 15 kWh/m^2.yr (Space heating demand)	
Energy Use Intensity (EUI) (kWh/m2GIA/yr) *Maximise energy efficiency*	*Not applicable*	Excellent (BREEAM Ene 01) *Outstanding from 2028*	Excellent (BREEAM Ene 01)	*Outstanding from 2028*
PV footprint area (% of ground floor footprint (fp)) *Use renewable energy*	% fp (PVs installed)	% fp (PVs installed)	% fp (PVs installed)	
Fossil fuel free (yes/ no) *Use low carbon energy*	Yes (Fossil fuel free)	Yes (Fossil fuel free)	Yes (Fossil fuel free)	
TM52 met and passed (yes/no) *Reduce overheating risk*	*Not applicable*	Yes (CIBSE TM52 pass)	Yes (CIBSE TM52 pass)	
Upfront embodied carbon (kgCO_2e/m$^2_{GIA}$) *Minimise embodied carbon*	Summary of efforts (Upfront embodied carbon)	Summary of efforts (Upfront embodied carbon)	kg/CO"e (Upfront embodied carbon)	
Offset contribution (£) *Offsets*	*Not applicable*	*Not applicable*	£ (Offsets)	*Options for offsetting currently under development and to be adopted by each local authority.*

3

Net Zero operational carbon design

Building design measures for Net Zero operational carbon

The most successful Net Zero Carbon buildings are designed that way from the moment pen is put to paper. While construction specifications can be improved to meet Net Zero, this can come at a capital cost premium if not carried out alongside sustainable design. Therefore, it is more effective to design for a compact building form, optimal orientation, and window areas tailored for orientation. These sustainable design decisions when taken alongside those responding to local context and design codes, significantly reduce the energy consumption of buildings and improve user comfort.

Minimise energy demand

Building form

The thermal envelope of the building should be as simple as possible. This reduces the exposed surface area for heat loss and reduces the complexity of construction. However, the thermal envelope is sometimes different to the visual massing and is defined by a continuous insulation line enclosing all warm spaces in the building.

The orientation and massing of the building should be optimised to allow solar gains and prevent significant overshadowing in winter.

Window design

Window design should consider orientation, daylight and summer comfort, and should work in tandem with other architectural design factors like proportion and elevational composition.

Excessive glazing is the main cause of overheating in the summer and heat loss in the winter.

Natural and mechanical ventilation

Effective ventilation is vital for ensuring good indoor air quality, the ability to mitigate heat build-up and to remove excess moisture. Buildings should include background and purge ventilation:

Background ventilation should provide a constant rate of ventilation throughout the day and across the seasons. All buildings need adequate background ventilations and the most efficient way of providing this is through mechanical ventilation with heat recovery (MVHR) for background ventilation.

Purge ventilation is in addition to background ventilation and provides bursts of fresh air to rapidly cool or renew the indoor air, typically achieved with openable windows.

Highly insulated building fabric

Buildings will require high levels of insulation to reduce heat loss. It is important the insulation is thick enough to meet the U-value required and that junctions are well insulation to prevent thermal bridging.

Once the building envelope has been made energy efficient there are two more steps to take: include an efficient and low carbon heating system and generate on-site renewable energy.

Maximise energy efficiency

Heating systems

Making informed decisions about the heating system has a significant impact on the overall carbon performance. The design team should use this guidance to inform design measures used to deliver the best low carbon heat solution possible.

Avoid using fossil fuels on-site altogether.

Use renewable energy

Photovoltaic (PV) electricity generation

Net Zero Carbon can only be achieved by intensifying electricity generation on site, which is best achieved through considering opportunities for PV at an early design stage. Designing the roof to maximise the number of PV panels and minimise over-shading can significantly increase the total amount of solar energy generated on-site.

The following pages in this section explain the design measures included in these steps in more detail for both residential and non-residential buildings.

3.1

Residential Net Zero operational carbon design

Residential - energy efficient building design

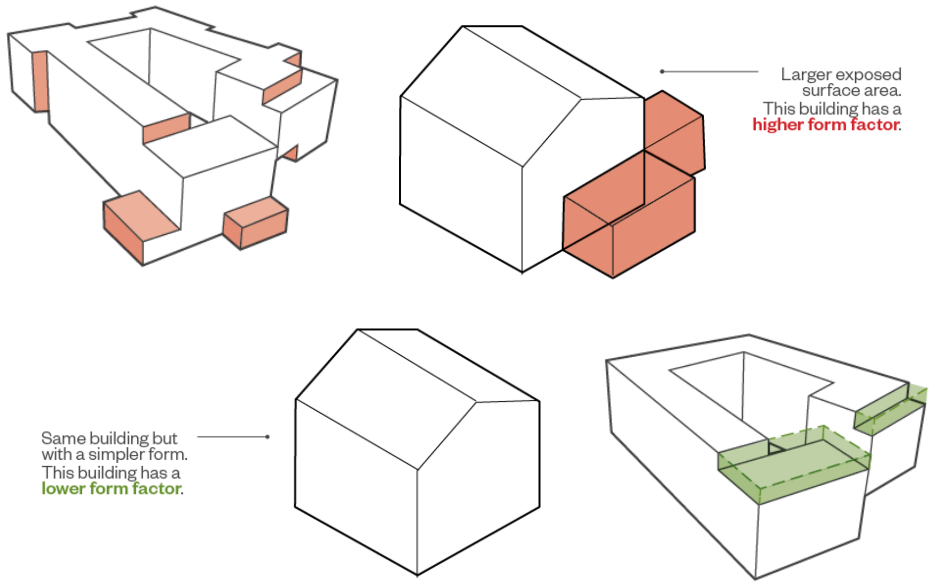
1 Compact building form

Simplify the form of buildings and be selective and measured about the number of features used

Decreasing the external surface area of the building results in reduced heat loss and therefore less energy needed for space heating. This can be quantified by the form factor.

The lower the form factor the more energy efficient the building is. A form factor of below 2 is typically expected for houses and mid-rise apartment buildings. Denser developments can aim for 1-1.5. Detached bungalows tend to have the poorest form factor of between 2-3.

Be strategic about adding articulation to the building form. Emphasise a few key design features well, such as those listed in local design codes, that really matter in the context. The fewer combinations of feature such as stepped roofs, roof terraces, overhangs and inset balconies or decks, the lower the heat loss from the building.



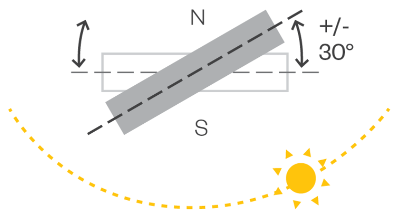
$$\text{Form factor} = \frac{\text{Exposed external surface area}}{\text{Gross internal floor}}$$

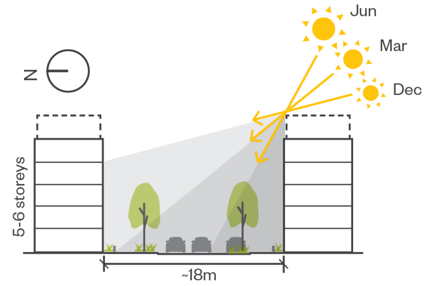
2 Heat from the sun in the winter

Review the orientation of buildings and encourage south facing dwellings.

Prioritise dual aspect, south-facing dwellings where possible within context constraints. Overheating risk increases proportionally as the building faces away from due south. Anything beyond +/- 30° is no longer a south-facing façade.

Avoid overshadowing of buildings where possible, this reduces the heat gain from the sun in winter. Allow 1-1.5m of distance for every 1m of height.





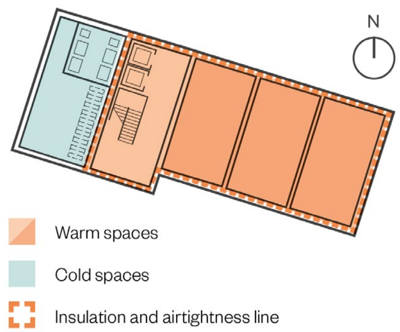
3 Space for unheated facilities

Review where cold spaces are located and ensure they are grouped.

Keep cold spaces, such as bin/bike stores and substations, separate or towards the north end of buildings where possible. Group cold spaces rather than pepper-potting them across the ground floor.

When these spaces are neighbouring a warm part of the building, such as a dwelling, the party wall and separating floor above need to be highly insulated.

Draw the insulation and airtightness line around dwellings early and consider whether circulation space should be within or outside of the insulated and airtight volume.



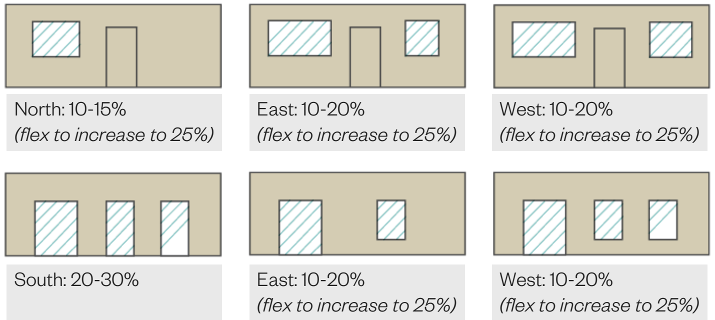
Residential - energy efficient building design

4 Elevations to balance heat gain, heat loss and daylight

Review windows areas based on orientation.

The glazing-to-wall ratios are a key feature of energy efficient design. It is important to minimise heat loss to the north (using smaller windows) while providing sufficient solar heat gain from the south (using larger windows).

Encourage design teams to consider which way a dwelling faces. It is much easier to design smaller windows facing access decks or fronts of homes and larger windows facing balconies or gardens. Therefore, try to orientate homes accordingly. Use the below window proportions as a starting guide. Flexibility exists in the proportions where the form factor has been reduced, favourable orientation used and appropriate shading added.



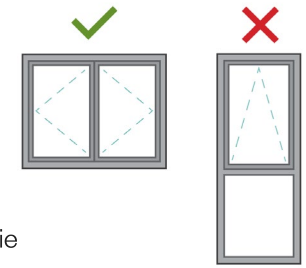
Deck facing elevations or front elevations

Balcony or garden facing elevations

Horizontal works better than vertical

Wider, shorter windows:

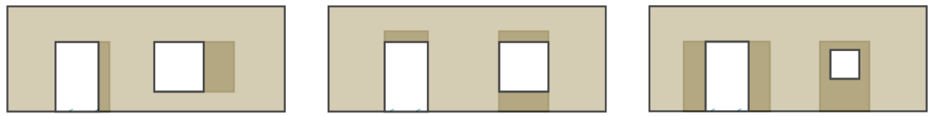
- Improve daylight distribution in rooms
- Increase openable area for ventilation
- Provide increased privacy to bedrooms
- Moderate overheating risk and are typically easie



Local context or other design factors may mean this optimal approach is not always possible. Consider how windows open for effective ventilation. Side hung windows provide larger opening areas than top hung. Inward opening windows are easier for residents to clean than outward opening. Consider clashes with internal or external shading devices, fittings and furniture.

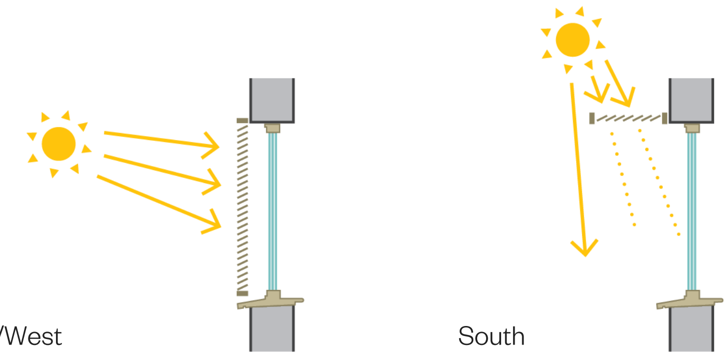
Trick the eye

Trick the eye using architectural features. Windows sized to balance heat loss and gain can sometimes appear ungenerous. Appropriate introduction of architectural features can improve the balance of solid to 'apparent' void. For example, use of stepped reveals or textured panels.



Solar shading

Prioritise living areas with larger windows on the south. It is easier to design fixed shading on the south for summer while allowing heat gains in winter.



East/west orientations have a higher overheating risk due to low-angle sun. Reduce glazed areas and include shading on the west, e.g. with shutters.

High angle sun can be controlled using horizontal shading or balconies above windows. External moveable shutters are also suitable.

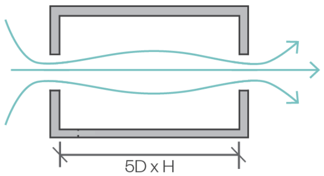
Residential - fabric and ventilation specification

5 Natural ventilation

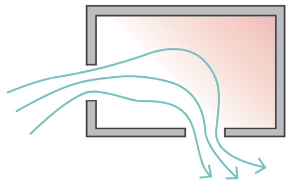
Review the natural ventilation strategy and encourage cross ventilation.

All habitable rooms in a home should have openable window(s).

- Dual aspect dwellings allow for cross ventilation – the most effective form of natural ventilation, particularly when windows are on opposite sides. Single aspect homes are the least effective at ventilating and are at risk of overheating.
- Always provide multiple openings, with a large opening area and different sizes, to allow the occupant to control their environment.



Optimum dual aspect
Cross ventilation



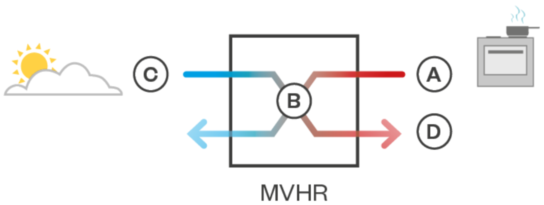
Corner aspect
Alternative to cross vent

6 Mechanical ventilation with heat recovery (MVHR)

Review where MVHR units are located and ensure they are close to external walls.

MVHR units provide background ventilation by extracting moist warm air from kitchens and bathrooms (A), exchanging the heat (B) to incoming fresh air (C), and then supplying the air (D) to the other rooms in the home.

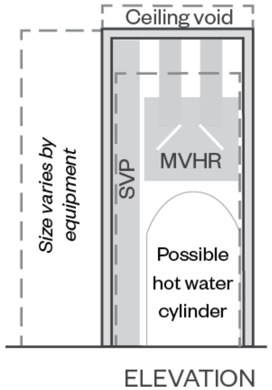
The heat recovery can be automatically bypassed in summer.



Utility cupboard size

A full height services cupboard is often required to contain heating and ventilation equipment. This could include for example, a mechanical ventilation with heat recovery (MVHR) unit, a hot water cylinder or exhaust air heat pump. In apartments washing machines may also be placed in stores.

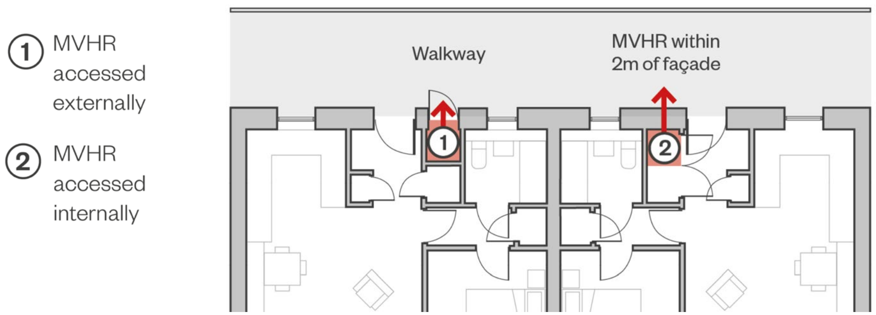
Where MVHR is included, ducts will likely be distributed in the ceiling.



Utility cupboard position

MVHR units are located inside home, but can be made accessible internally or externally to suit the client's maintenance and repair preferences. It does not need to be in the same cupboard as the heating equipment or hot water tank. Locate the MHVR on or within close proximity of an external wall to keep the intake and exhaust ductwork less than 2m long.

Noise from the MVHR should be no more than 35dB(A) to reduce disturbance to occupants. Avoid locating MVHR's in a bedroom or living room.



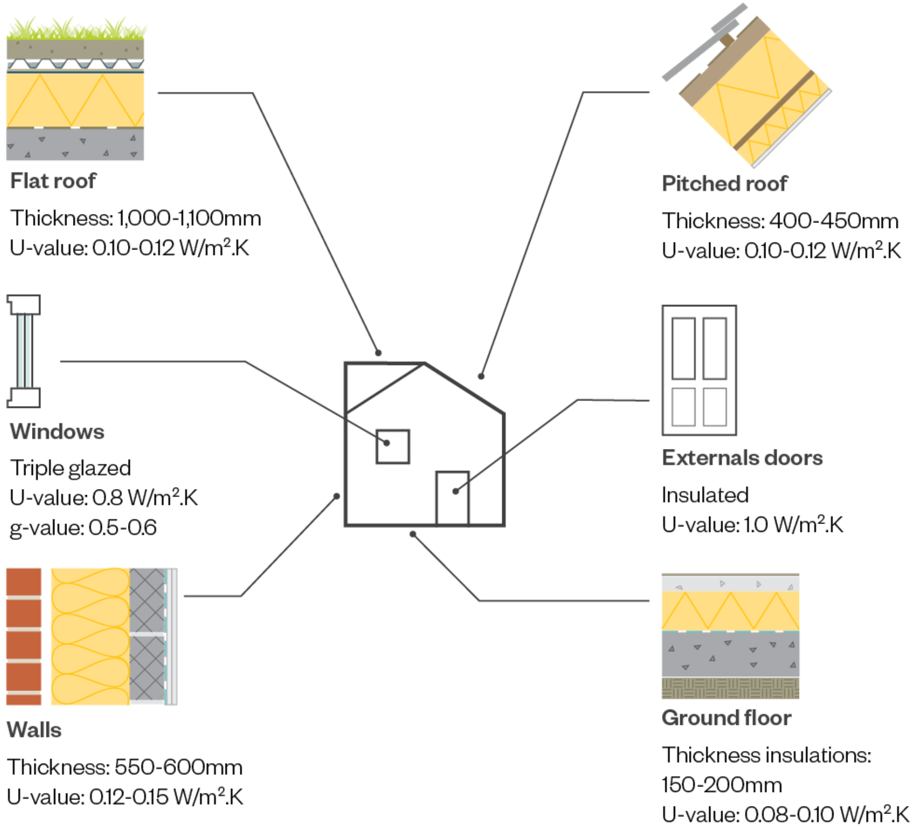
Residential - fabric and ventilation specification

7 Highly insulated building fabric

Allow for insulation thickness in overall construction build-ups

Element thickness and thermal performance (U-value) will vary depending on the form factor and use of the building. The below construction build-ups are intended to be a useful starting point. Flexibility exists in the insulation thickness where the form factor has been reduced and favourable orientation used.

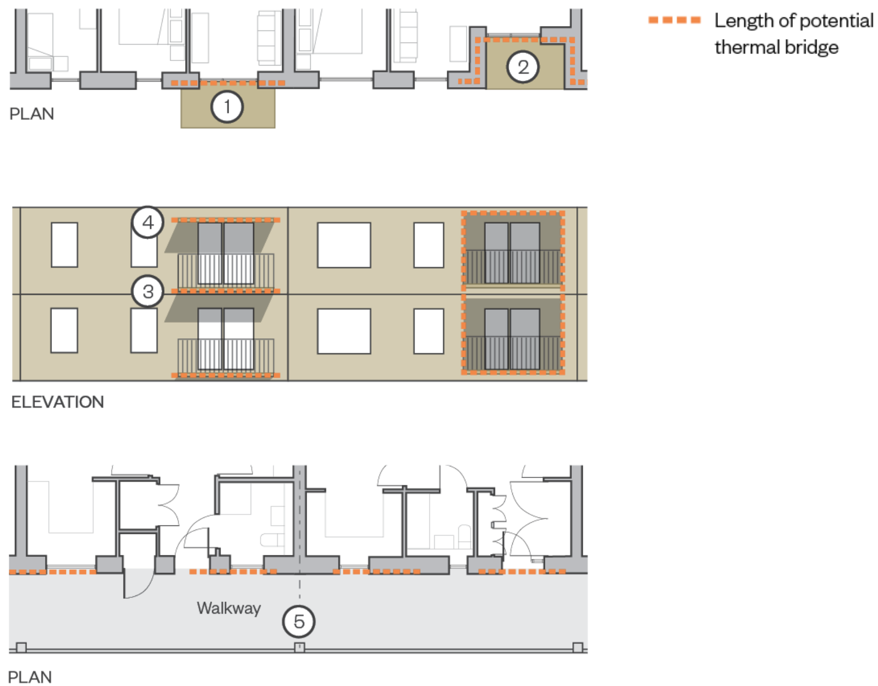
Air permeability - An extremely airtight building fabric would have an air permeability of < 1 $m^3/h/m^2$ at 50 Pa. For small minor schemes an air permeability of at least < 3 $m^3/h/m^2$ at 50 Pa would be good practice.



8 Balconies and access walkways

Balconies can have an impact on thermal bridging, consider the balcony type and length of thermal bridge.

1. Projecting balconies have the least impact on daylight and energy efficiency.
2. Inset balconies increase the form factor, area of external wall and length of thermal bridges. Where inset balconies are desirable for context or layout reasons and cannot be avoided, compensations should be made elsewhere.
3. Aim for stacked balconies to give useful shading to south-facing windows below.
4. Consider providing shade for the top floor window.
5. The structure of access walkways should be lightweight to avoid heavily shading the façade.

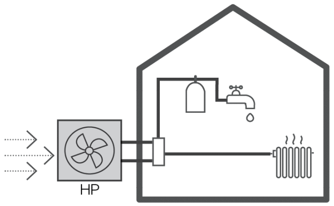


Residential - low carbon heating - individual heating systems

Various low carbon heating options are available for residential developments. A handful of options have been shown on this page and the next to illustrate some relevant examples.

Air source heat pump (ASHP)

Air to water monobloc



Low grade heat is gathered from the external air by the Air Source Heat Pump, which uses electricity efficiently to upgrade the heat to a higher temperature – typically 45°C for space heating and 60°C for hot water. Hot water is stored in an individual hot water tank in each unit.

Pros:

- Low distribution losses
- Low impact on overheating

Cons:

- Visual impact of external unit

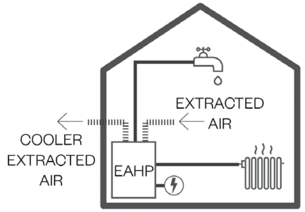
Key design considerations:

- Each dwelling requires an individual external heat pump unit no more than 10m from (and ideally much closer to) the dwelling.
- Radiators must be sized for a 45°C flow temperature
- Refrigerant choice is key to keeping the system embodied carbon low.

TANZ suitability | £ energy bills

Exhaust air heat pump (EAHP)

Compact unit



Combines mechanical ventilation, heat recovery and a heat pump system in one unit. The warm extracted air is passed through a heat exchanger, where heat is transferred to the incoming air. The heat pump uses electricity to upgrade the heat to a higher temperature. Hot water is stored in an integrated hot water tank.

Pros:

- No external unit required
- Low distribution losses
- Low impact on overheating
- Some units can provide an element of cooling

Cons:

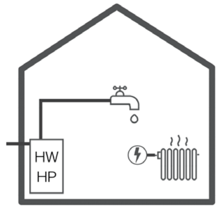
- Potential increased ventilation rates to suit the need of the air source heat pump
- Capital and maintenance costs

Key design considerations:

- EAHPs tend to have a limited capacity and therefore work in small homes or those with a high level of fabric thermal efficiency
- Ideally position the EAHP within 2m of an external wall
- Radiators must be sized for a 45°C flow temperature.
- Refrigerant choice is key to keeping the system embodied carbon low.

TANZ suitability | ££ energy bills | MVHR included

Hot water heat pump + direct electric



Space heating and domestic hot water are provided separately. Space heating is provided through electric panel heaters and domestic hot water through a packaged hot water heat pump located within the dwelling.

Pros:

- No external units required
- Low distribution losses
- Low impact on overheating

Cons:

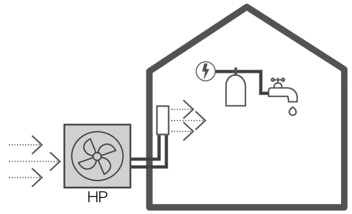
- Maintenance costs
- Higher operating costs and carbon emissions (electric space heating)

Key design considerations:

- Direct electric space heating requires high thermally performing fabric to reduce occupants' heating costs
- The hot water heat pump needs to be close to an external wall
- Additional electric demand in cold weather for the space heating.
- Refrigerant choice is key to keeping the system embodied carbon low.

TANZ suitability | ££ energy bills

Air to air heat pump + direct electric



The external heat pump is connected by pipework carrying refrigerant to convector units in the main rooms, these can either heat or cool the rooms. Domestic hot water is provided through an electric immersion heater in the hot water tank. The systems are not connected.

Pros:

- Low space heating costs
- Low distribution losses
- Low impact on overheating
- Potential for active cooling

Cons:

- Visual impact of external unit
- Moderate operating costs and carbon emissions (electric domestic hot water)

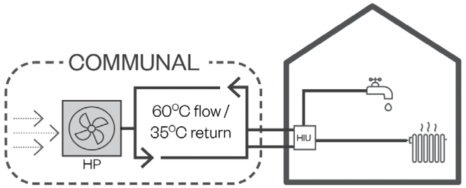
Key design considerations:

- Each dwelling requires an individual external heat pump unit
- Refrigerant choice is key to keeping the system embodied carbon low.

TANZ suitability | ££ energy bills

Residential - low carbon heating - communal systems (building or district)

Communal air source heat pump



A communal bank of air source heat pumps is located on the roof of the building. Heat is distributed to each flat via 'standard' heating pipes to a Heat Interface Unit (HIU).

Pros:

- No individual external units required (only communal ones)
- Communal maintenance

Cons:

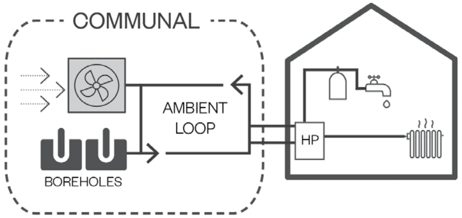
- Distribution losses
- Contribution to overheating risk
- Individual metering and billing required

Key design considerations:

- Allow enough space on the roof of each building for the heat pumps and associated plant
- Consider acoustic impact of the roof mounted air source heat pumps
- Adequate ventilation to communal areas to mitigate overheating risk from system pipework.
- Refrigerant choice is key to keeping the system embodied carbon low.

TANZ suitability | ££ energy bills | Overheating risk

Communal ambient loop



A communal bank of air source heat pumps is located on the roof of the building and/or water is circulated in boreholes. Heat is distributed to each flat via a loop flowing at an ambient temperature. Within each dwelling, a heat pump unit uses electricity to upgrade the heat from the communal ambient loop to a higher temperature.

Pros:

- No individual external units required
- Low distribution losses
- Low impact on overheating risk
- Potential for active cooling

Cons:

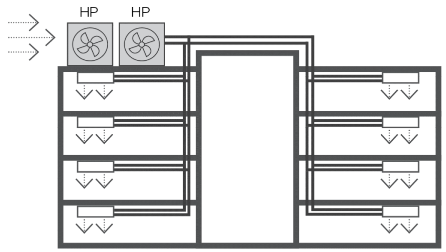
- High capital cost
- Individual metering and billing may be required

Key design considerations:

- Allow enough space on the roof of each building or suitable space and ground conditions for ground array
- Consider acoustic impact of the roof mounted air source heat pumps.
- Refrigerant choice is key to keeping the system embodied carbon low.

TANZ suitability | £ energy bills

Variable Refrigerant Flow System (VRF)



A group of Air Source Heat Pumps usually located on a roof connect to ceiling mounted cassette units throughout the building, these can either heat or cool the space they are in. It is possible to have some heating while others are cooling at the same time.

Pros:

- Low space heating costs
- Low distribution losses
- Combined heating and active cooling system

Cons:

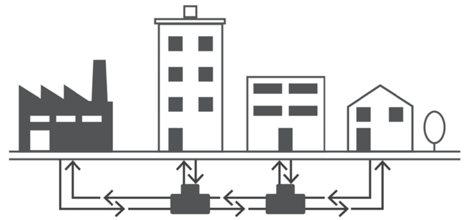
- High volume of refrigerant used in extensive pipework system – choice of refrigerant is critical to keeping embodied carbon low
- Usually more suited to commercial developments, rather than dwellings.

Key design considerations:

- Separate ventilation system required
- Consider acoustic impact of the roof mounted air source heat pumps.
- Refrigerant choice is key to keeping the system embodied carbon low.

TANZ suitability | £ energy bills

District heating network



District heating uses a central heat source to distribute hot water through a network of pipes to multiple dwellings, connecting several buildings together. This heating system goes beyond the scale of an apartment building.

Pros:

- No external units required on individual buildings (except the energy centre)
- Maintenance of main plant is centralised

Cons:

- High distribution losses
- Contribution to overheating risk
- Individual metering and billing required

Key design considerations:

- Avoid fossil fuel based heat networks
- High impact on overheating
- High cost and disruption of installing the hot water network pipes
- Consumer protection concerns for residents who are tied in to heat contracts.

TANZ suitability | ££ energy bills | Overheating risk

Residential - renewable energy

Three common roof design approaches are illustrated below to demonstrate the potential roof area covered by PV for a medium density apartment block, and to guide the design team towards best practice roof design.

1 Maximise PV panel density

For flat roofs use an east/west concertina PV array to maximise density and avoid inter-row shading.

Alternatively, where suitable consider a large south facing mono-pitch roof to maximise solar electricity generation.

Typical mounting system (© K2 systems)

Example concertina array

2 Simplify roof form

Stepped roofs and built in terraces will reduce the available roof area for solar panels.

3 Minimise shading

Reduce parapet heights and/or replace with guard rails to minimise shading PV panels.

Reposition plant areas, stair cores and lift overruns to the north of the roof where possible.

4 Specify high performing PV

Key elements of the PV system specification should be optimised:

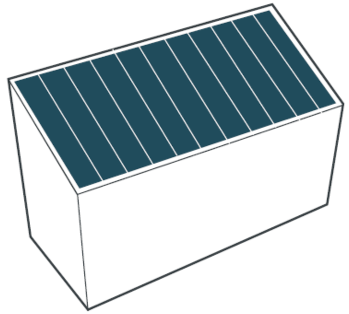
Specify high efficiency monocrystalline silicon solar panel panels from a reputable manufacturer with an output of at least 450W per panel. Include either microinverters or DC optimisers in the system to ensure panels operate at their peak output.

5 Check energy balance

Where possible the renewable energy generation on-site should equal the total predicted energy use, in order to achieve a zero carbon balance.

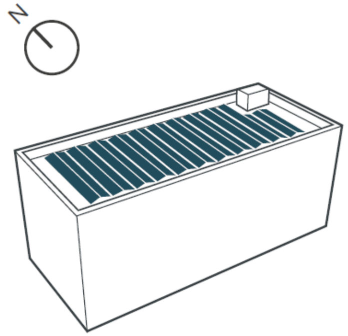
Post-completion an energy balance calculation could be made on an annual basis to determine if the building or development achieves a Net Zero Carbon balance in reality.

Use of a green tariff alone would not be robust enough and does not provide 'additional' renewables.



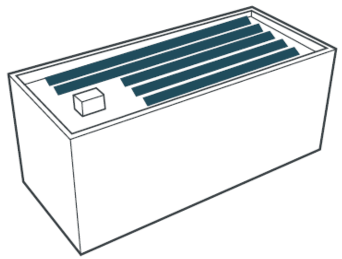
Optimised roof design

Roof has been designed to maximise area of PV.



Maximised roof design

PV area has been maximised within roof area. PV layout using an east-west facing concertina array maximises the number of panels able to fit on the roof. Plant and lift overruns are positioned efficiently and reduce overshading to PV.



Business as usual roof design

PV area has been set out within roof area but the layout has not been optimised to maximise the number of PV (use of a south facing array). Plant and lift overruns are positioned in less favourable locations.

3.2

Non-residential Net Zero operational carbon design

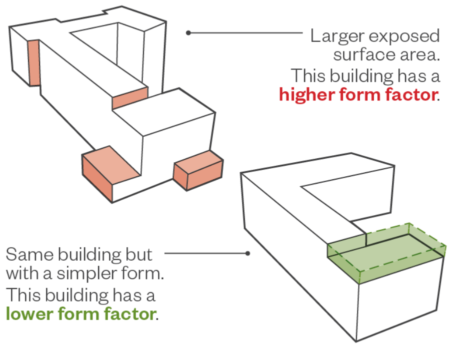
Non-residential - offices - energy efficient building design

1 Compact building form

Simplify the form of the building

Decreasing the surface area of the building results in reduced heat loss and therefore less energy consumption for space heating and cooling . This can be quantified by the form factor.

The lower the form factor the more energy efficient the building is. A form factor between 1 and 2 is typically expected for office buildings.

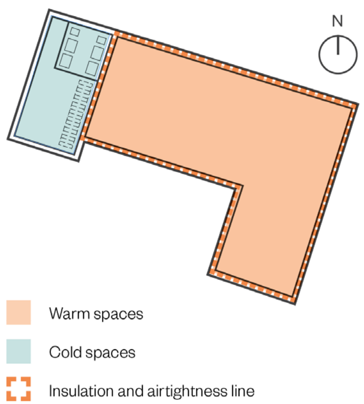


$$\text{Form factor} = \frac{\text{Exposed external surface area}}{\text{Gross internal floor}}$$

2 Space for unheated facilities

Review where cold spaces are located and ensure they are grouped

Keep cold spaces, such as bin/bike stores and substations, separate or towards the north end of buildings. Group cold spaces rather than pepper-potting them across the ground floor. When these spaces are neighbouring a warm part of the building, the party wall and separating floor above need to be highly insulated. Draw the insulation and airtightness line on plans and sections.

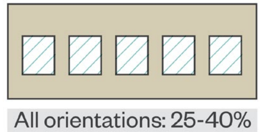


3 Elevations to balance heat gain, heat loss and daylight

Review windows areas and base shading design on orientation

Balance window areas for heat gain, heat loss and good internal daylight. To reduce internal lighting loads window to wall glazing area of 25-40% can be used on all elevations.

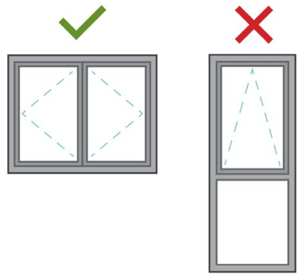
Include glare control through installation of internal blinds.



Horizontal works better than vertical

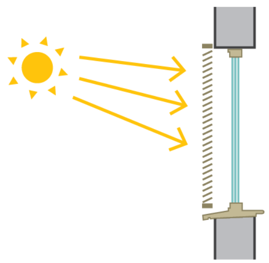
Wider, shorter windows:

- Improve daylight distribution in rooms
- Increase openable area for ventilation
- Reduce overheating risk while promoting daylight
- Typically easier to shade
- Allow furniture to be placed next to windows.



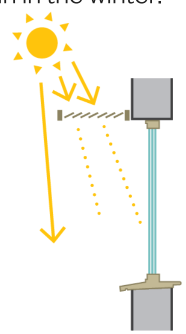
Solar shading

Energy efficient office buildings often require more cooling than heating. Therefore, appropriate external shading must be included in the design. Use of solar control glass is also an option, however, this reduces free heat from the sun in the winter.



East/West

East/west orientations have a higher overheating risk due to low-angle sun. Include movable external shading on the east and west.



South

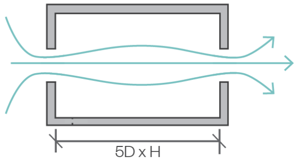
High angle sun can be controlled using horizontal shading above the window. Externa moveable shutters are also suitable.

Non-residential - offices - energy efficient building design

4 Natural ventilation

Review the natural ventilation strategy and encourage cross ventilation.

Where possible, include openable windows.
Cross ventilation is the most effective form of natural ventilation, particularly when windows are on opposite sides.

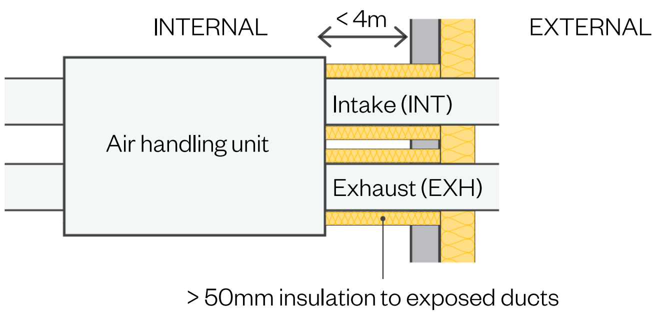


Cross ventilation
Most effective

5 Mechanical ventilation

Consider the zoning of the ventilation system to make sure that the air flow can be matched as closely as possible to the areas in use, e.g. outside normal occupied hours or where different companies/groups occupy the same building. Focus on the ventilation system control and ensure it is able to respond to variations in occupancy.

Ensure the most efficient heat recovery possible is used. Encourage design teams to locate the air handling units within close proximity of an external wall to keep the intake and exhaust ductwork to a minimum.



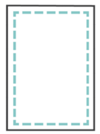
Noise from the ventilation system should be limited to:

Offices	≤ 25 db(A)	Applies to rooms with prolonged occupancy
Other occupied rooms	≤ 30 db(A)	i.e. communal spaces
Breakout from plant cupboard	≤ 35 db(A)	This is the maximum sound from the AHU unit in the corridor.

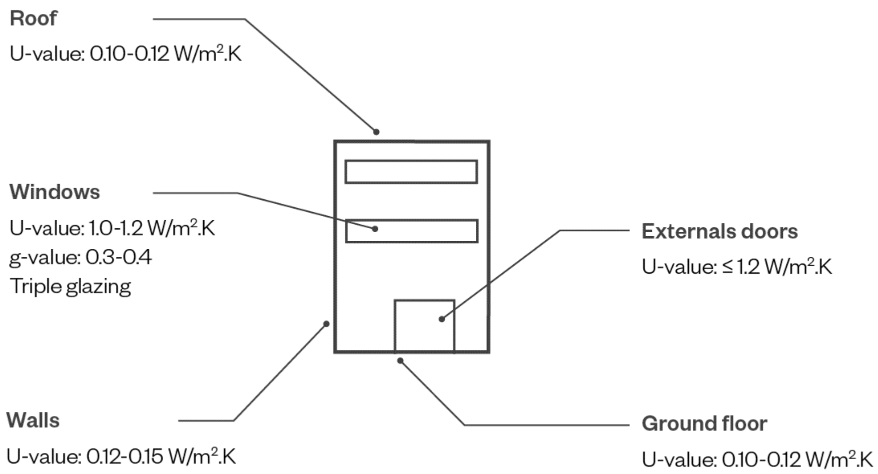
6 Highly insulated building fabric

Allow for insulation thickness in overall construction build-ups

Element thickness and thermal performance (U-value) will vary depending on the form factor and use of the building. The below construction build-ups are intended to be a useful starting point.



Air permeability - An extremely airtight building fabric would have an air permeability of < 1 $m^3/h/m^2$ at 50 Pa. For small minor schemes an air permeability of at least < 3 $m^3/h/m^2$ at 50 Pa would be good practice.

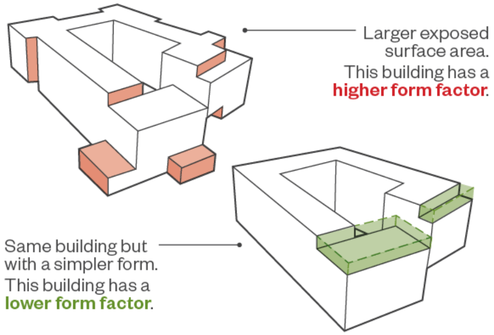


Non-residential - schools - energy efficient building design

1 Compact building form

Simplify the form of buildings and be selective about the number of features used

Decreasing the surface area of the building results in reduced heat loss and therefore less energy consumption for space heating. This can be quantified by the form factor. The lower the form factor the more energy efficient the building is. A form factor between 2 and 3 is typically expected for school buildings.

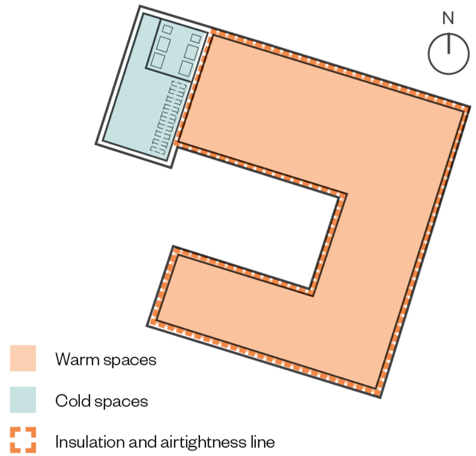


$$\text{Form factor} = \frac{\text{Exposed external surface area}}{\text{Gross internal floor}}$$

2 Space for unheated facilities

Review where cold spaces are located and ensure they are grouped

Keep cold spaces, such as bin/bike stores and substations, separate or towards the north end of buildings where possible. Group cold spaces rather than pepper-potting them across the ground floor. When these spaces are neighbouring a warm part of the building, the separating wall and floor above need to be highly insulated. Draw the insulation and airtightness line on plans and sections.

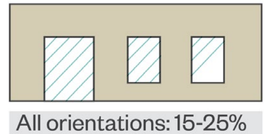


3 Elevations to balance heat gain, heat loss and daylight

Review windows areas and base shading design on orientation

Balance window areas for heat gain, heat loss and good internal daylight. To achieve this window to wall glazing areas of 15-25% can be used on all elevations.

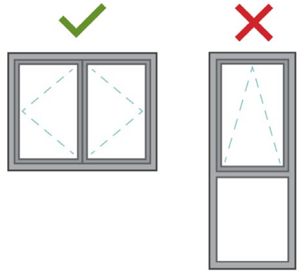
Include glare control through installation of internal blinds.



Horizontal works better than vertical

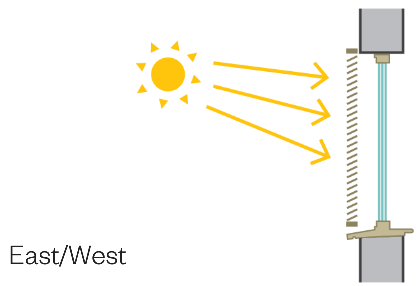
Wider, shorter windows:

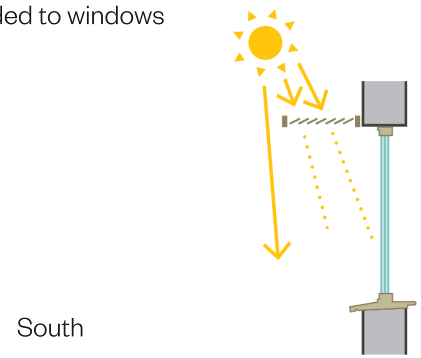
- Improve daylight distribution in rooms
- Increase openable area for ventilation
- Reduce overheating risk while promoting daylight
- Typically easier to shade
- Allow furniture to be placed next to windows.



Solar shading

Appropriate external shading must be provided to windows and rooflights.





East/west orientations have a higher overheating risk due to low-angle sun. Include movable external shading on the east and west.

High angle sun can be controlled using horizontal shading above windows. External moveable shutters are also suitable.

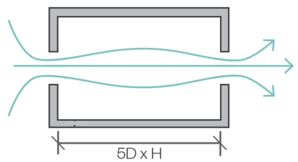
Non-residential - schools - energy efficient building design

4 Natural ventilation

Review the natural ventilation strategy and encourage cross ventilation

Unless deemed unsuitable, include openable windows to all rooms.

Cross ventilation is the most effective form of natural ventilation, particularly when windows are on opposite sides.

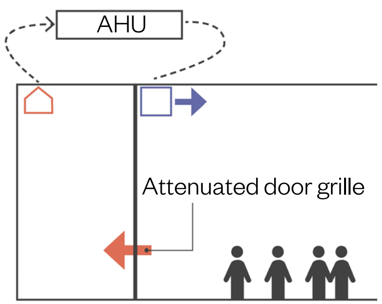


Cross ventilation
Most effective

5 Mechanical ventilation

Consider the zoning of the ventilation system to make sure that the air flow can be matched as closely as possible to the areas in use, e.g. halls and sports facilities may be used in evenings and weekends when classrooms are not. Focus on the ventilation system control and ensure it is able to respond to variations in occupancy.

'Cascade' ventilation systems can be used to reduce the number of fans and the lengths of ducts if the building layout and fire compartmentation is suitable.

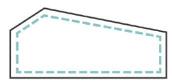


Ensure the most efficient heat recovery possible is used. Encourage design teams to locate the air handling units within close proximity of an external wall to keep the intake and exhaust ductwork to a minimum.

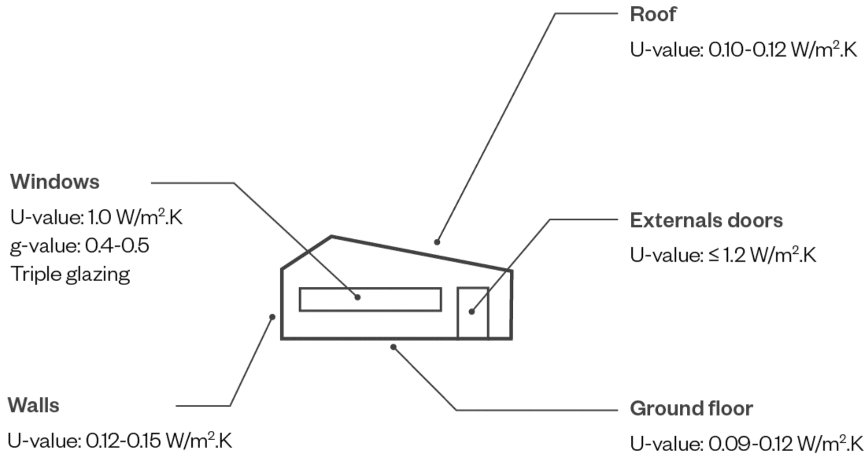
6 Highly insulated building fabric

Allow for insulation thickness in overall construction build-ups

Element thickness and thermal performance (U-value) will vary depending on the form factor and use of the building. The below construction build-ups are intended to be a useful starting point.



Air permeability - An extremely airtight building fabric would have an air permeability of < 1 $m^3/h/m^2$ at 50 Pa. For small minor schemes an air permeability of at least < 3 $m^3/h/m^2$ at 50 Pa would be good practice.



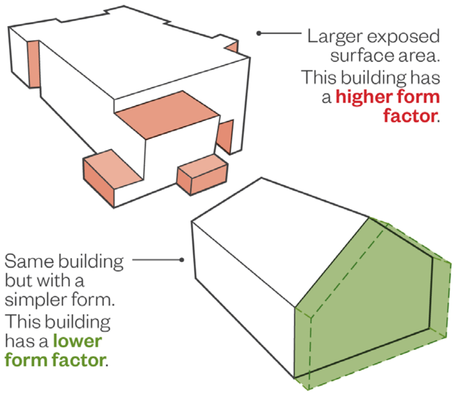
Non-residential - industrial - energy efficient building design

1 Compact building form

Simplify the form of the building

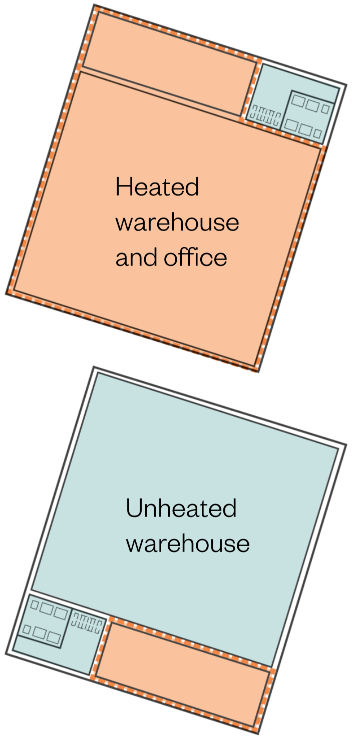
Decreasing the surface area of the building results in reduced heat loss and is more efficient to build. This can be quantified by the form factor.

The lower the form factor the more energy efficient the building is.



$$\text{Form factor} = \frac{\text{Exposed external surface area}}{\text{Gross internal floor}}$$

2 Space for unheated facilities



Review where cold spaces are located and ensure they are grouped

Keep cold spaces separate or towards the north end of buildings where possible.

Decide from an early stage if spaces such as warehouse workshops will be heated or unheated, to locate them appropriately. Consider that small warehouse-type buildings in business parks often get used for alternative uses which results in heated warehouses.

Draw the insulation and airtightness line on plans and sections.

Warm spaces

Cold spaces

Insulation and airtightness line

3 Balance heat gain, heat loss and daylight

Industrial buildings typically have few windows but include rooflights

Orientate rooflights north to minimise risk of overheating and optimise consistent daylight. South facing pitches can then be used for PV panels.

For small office areas, balance window areas for heat gain, heat loss and good internal daylight. To reduce internal lighting loads window to wall glazing area of 25-40% can be used on office elevations.

Include glare control through installation of internal blinds.

4 Mechanical ventilation with heat recovery (MVHR)

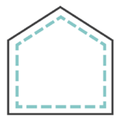
Focus on the ventilation system control and ensure it is able to respond to variations in demand, depending on the occupancy and/or processes.

Ensure the most efficient heat recovery possible is used and air handling units are located within close proximity of an external wall to keep the intake and exhaust ductwork to a minimum.

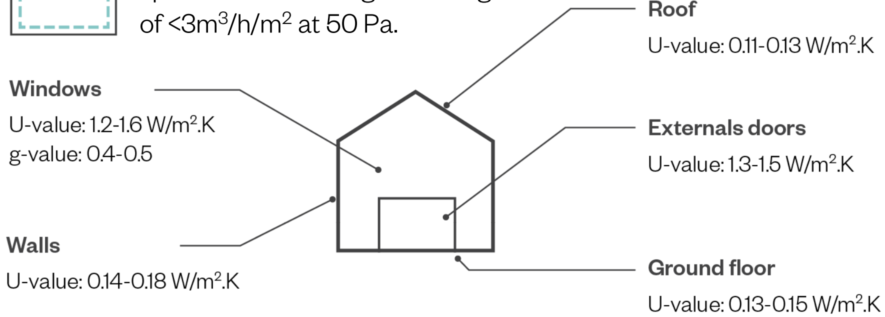
5 Highly insulated building fabric for warm spaces

Allow for insulation thickness in overall construction build-ups

Element thickness and thermal performance (U-value) will vary depending on the form, use of the building and whether warehouse spaces are heated or un-heated. For small warehouses on business parks, insulate the warehouse as if it is to be heated. The below construction build-ups are intended to be a useful starting point for heated spaces.



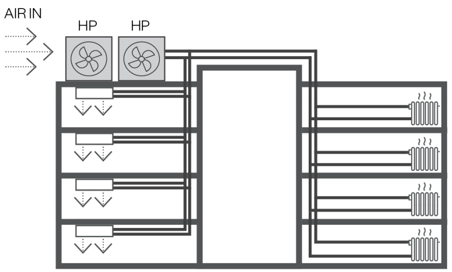
Air permeability – For heated spaces seek an airtight building fabric of <3m³/h/m² at 50 Pa.



Non-residential - low carbon heating and cooling

Various low carbon heating options are available for non-residential developments. A handful of options have been shown on this page and the next to illustrate some relevant examples.

Air source heat pump



A central group of air source heat pumps is located on the roof of the building. Heat is distributed to each floor via 'standard' heating pipes to connect to heat emitters such as fan coil units or radiators.

Cons:

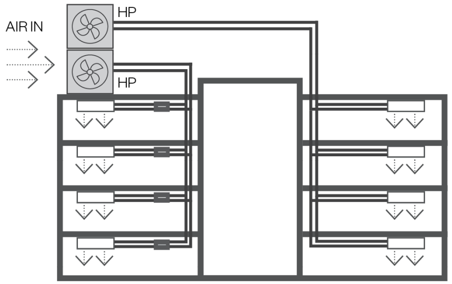
- Separate cooling system required.
- Moderately poor energy efficiency.

Key design considerations:

- Allow enough space on the roof of each building for the heat pumps and associated plant
- Consider acoustic impact of the roof mounted air source heat pumps

££
energy bills

Hybrid / ambient loop



A central group of air source heat pumps is located on the roof of the building. The hybrid system has some refrigerant pipework centrally, connecting to heat exchangers in the building zones from which both heating and cooling water systems distribute to ceiling mounted fan coil units. The Versatemp system distributes ambient temperature water to a network of small heat pumps which can either heat or cool. Both systems allow simultaneous heating and cooling

Pros:

- Combined heating and active cooling system
- Good energy efficiency

Cons:

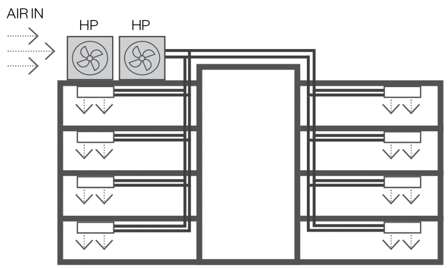
- Manufacturer specific solutions – potentially high capital cost

Key design considerations:

- Allow enough space on the roof of each building
- Consider acoustic impact of the roof mounted air source heat pumps

£
energy bills

Variable Refrigerant Flow System (VRF)



A group of Air Source Heat Pumps located on a roof connect to ceiling mounted cassette units throughout the building, these can either heat or cool. It is possible to have some heating while others are cooling at the same time.

Pros:

- Combined heating and active cooling system
- Good energy efficiency
- Low capital costs

Cons:

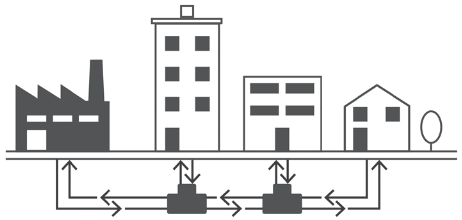
- High volume of refrigerant used in extensive pipework system – choice of refrigerant is critical to keeping embodied carbon low

Key design considerations:

- Allow enough space on the roof of each building
- Consider acoustic impact of the roof mounted air source heat pumps

£
energy bills

District heating network



District heating uses a central heat source to distribute hot water through a network of pipes to multiple buildings. This heating system goes beyond the scale of a single building.

Pros:

- No external units required on individual buildings (except the energy centre)
- Maintenance of main plant is centralised

Cons:

- High distribution losses
- Separate cooling system required.

Key design considerations:

- Avoid fossil fuel based heat networks
- High cost and disruption of installing the hot water network pipes
- Consumer protection concerns for residents who are tied in to heat contracts

££
energy bills

Non-residential - renewable energy

1 Maximise PV panel density

Where suitable consider south facing pitches (including sawtooth roofs) to maximise solar electricity generation.

Alternatively for flat roofs use an east/west concertina PV array to maximise density and avoid inter-row shading.

Industrial buildings in particular present a great opportunity for renewable energy generation.

2 Simplify roof form

Stepped roofs and irregular shaped roofs will reduce the available roof area for solar panels.

3 Minimise shading

Reduce parapet heights or replace with guard rails to minimise shading PV panels.

Reposition plant areas, stair cores and lift overruns to the north of the roof where possible.

4 Specify high performing PV

Key elements of the PV system specification should be optimised:

Specify high efficiency monocrystalline silicon solar panel panels from a reputable manufacturer with an output of at least 450W per panel. Include either microinverters or DC optimisers in the system to ensure panels operate at their peak output

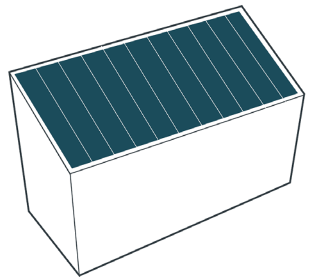
5 Check zero carbon balance

Where possible the designed energy generation intensity on-site should equal the total predicted energy use, in order to achieve a zero carbon balance.

Post-completion a carbon balance calculation should be made on an annual basis to determine if the building or development achieves a Net Zero Carbon balance in reality.

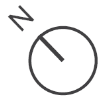
Use of a green tariff alone will not be robust enough and does not provide 'additional' renewables.

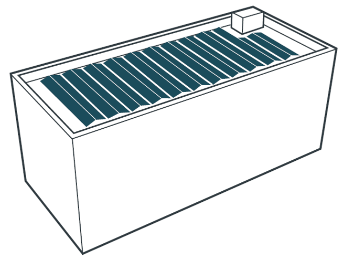
Four common roof design approaches are illustrated below to demonstrate the potential roof area covered by PV, and to guide the design team towards best practice roof design.



Optimised roof design

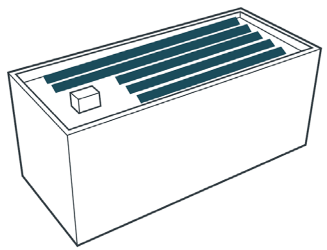
Roof has been designed to maximise area of PV.





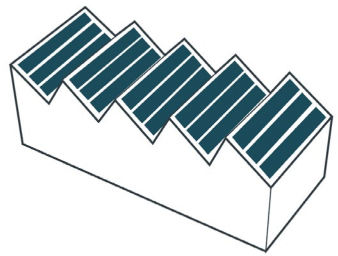
Maximised roof design

PV area has been maximised within roof area. PV layout using an east-west facing concertina array maximises the number of panels able to fit on the roof. Plant and lift overruns are positioned efficiently and reduce overshading to PV.



Business as usual roof design

PV area has been set out within roof area but the layout has not been optimised to maximise the number of PV (use of a south facing array). Plant and lift overruns are positioned in less favourable locations.



Sawtooth roof

A sawtooth roof has been used to combine south facing PV with north facing rooflights for an industrial building. Maximising energy available for generation while reducing energy consumed from internal lighting.

4

Designing for low embodied carbon

Building design measures for reduced upfront embodied carbon

Creating buildings that are efficient in material use, form and design from the outset can result in significant embodied carbon and cost reductions.

Decisions taken to reduce embodied carbon should be considered in tandem with decisions taken to reduce operational energy consumption. The focus should be on reducing embodied carbon alongside and in support of Net Zero operational carbon buildings, as opposed to trading one off against the other.

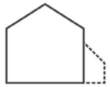
Upfront embodied carbon should be reduced for all development types and sizes through good design. To support this, upfront embodied carbon emissions (modules A1-A5) should be calculated and reported using RICS Whole Life Carbon Assessment for the Built Environment (2023). This is applicable to major residential and non-residential buildings. Large major development should also report life cycle embodied carbon emissions.

The following pages in this section provide guidance on how design can result in reduced upfront embodied carbon.

Reuse of existing buildings, structures elements and/or components

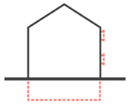
Where existing buildings or structures exist on-site, steps should be taken to first consider if they can be re-used. This section of the guidance focuses on how to reduce the upfront embodied carbon of new buildings through design. However, this is on the premise that consideration has already been given to the retention of existing buildings and structures on-site to allow them to be re-used or repurposed. Where demolition has been determined unavoidable, all attempts should be made to reuse or recycle materials removed from site.

Compact building form



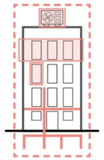
Designing compact buildings with less design complexities minimises the material volume and quantity needed for construction. It also simplifies the design and construction process, reducing waste, energy consumption and cost.

Transparency of design



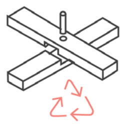
Understand the impact of non-typical features (e.g. basements) on the upfront embodied carbon emissions of the buildings and decide their importance in the project.

Lean structural, architectural and building services design



Lean design is crucial for reducing the upfront embodied carbon of the building. Designing more efficient and light-weight buildings reduces material use, the need for larger foundations and on-site material waste. Basements and podiums and transfer structures can significantly increase upfront embodied carbon on a project.

Impact of materials



Materiality choices have an effect on the energy efficiency, durability and lifespan, regulatory compliance and embodied carbon of the building. They also have a great impact on the indoor air quality and comfort of the residents and the environment. Therefore, designers need to choose materials with all these factors in mind and strike a balance between them.

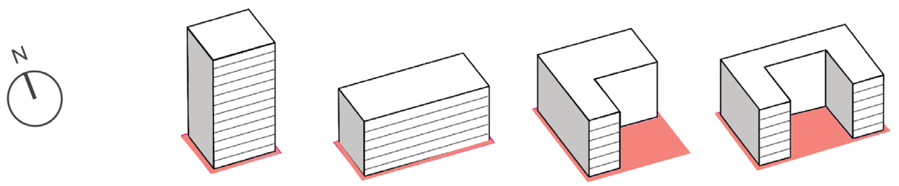
All buildings - efficient form design

1 Compact building form

The form of the building has an impact on the upfront embodied carbon of the structure and façade.

Simpler and compact building forms, as discussed in section 3, are more energy efficient. Features that make the building more complex, like overhangs, inset balconies and doorways, are harder to design and build, often needing extra structural support, costly special insulating products and can lead to more material waste during construction.

Illustration of the influence the form factor has on upfront embodied carbon of the façade.



	12 storey building GIA of 3455 m² (4 dwellings/floor)	6 storey buildings each with a gross internal floor area (GIA) of 3455 m² (8 dwellings/floor)		
Dual aspect	Yes	No	Partially	Yes
Form factor	0.88	0.88	0.95	1.13
Façade upfront embodied carbon* ($kgCO_2e/m^2$ GIA)	172	131	150	192
Density (dwellings/ha)	1333	702	487	486

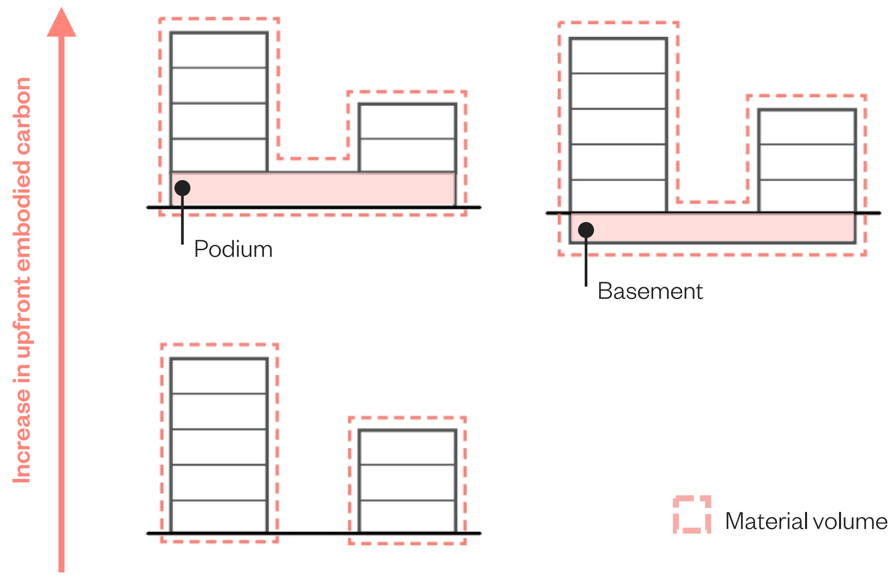
Note: There may be multiple influences that affect the decision to have dual aspect homes or high density sites. We should strive to understand the impact these design decisions make on all aspects of sustainability, from overheating through to operational energy and upfront embodied carbon.

*Window area is calculated according to the glazing percentages suggested in chapter 2. Assumed upfront embodied carbon for a brick and SFS façade is 260 $kgCO_2e/m^2$. *Source*: CWCT guidance 'How to calculate the embodied carbon of façades'. Assumed upfront embodied carbon for a triple-glazed window is 155 $kgCO_2e/m^2$. *Source*: Hawkins\Brown & LETI 'Embodied carbon primer'.

2 Transparency of design

Understand the importance of non-typical features in design and assess their impact on upfront embodied carbon.

Be transparent about how non-typical features, such as podiums or basements, can impact upfront embodied carbon compared to simpler alternatives. Consider communicating their implications on cost and material use, and if they are not required by the project brief suggest they are discarded. Features such as shading devices for overheating, dual aspect dwellings for cross ventilation and daylight, green or blue roofs for SUDs and biodiversity, or renewables should not be compromised. Instead, their benefits should be recognised while separately calculating their impact on upfront embodied carbon and reducing it where possible.



Podiums/basements involve complex construction techniques and require higher material usage (e.g. larger foundations and higher reinforcement and levels of insulation). Where possible, avoid the need for basements, podiums and transfer structures to reduce upfront embodied carbon.

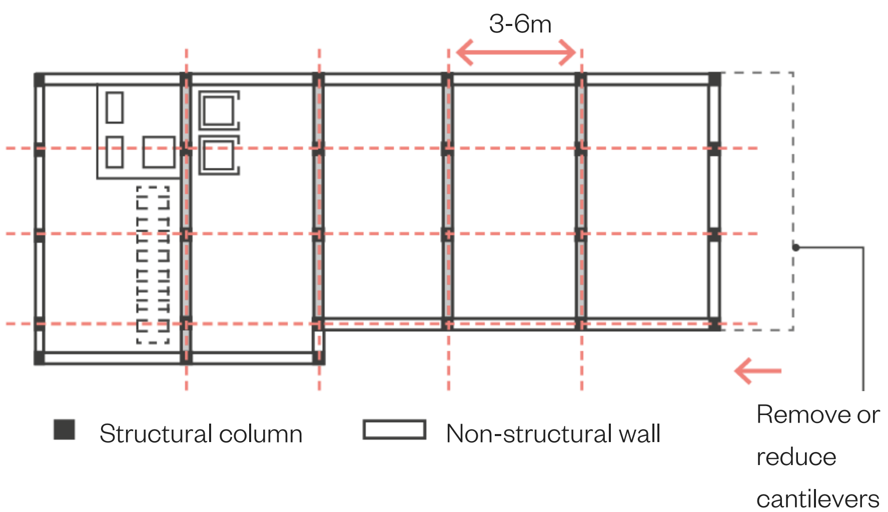
All buildings - structural and architectural lean design

3 Design 'lean' and 'light' structures

Sub-structure and superstructure often represent >50% of the upfront embodied carbon emissions in a building.

Build 'leaner' to reduce the volume of overall material used and build 'lighter' to help reduce the foundations. Considerations for reduction include:

- Grid spacing, location of the core and the structural depth all have significant impacts on material volumes. Optimise column grid (e.g. 3-6m) to decrease slab thickness and beam depths.
- Identify embodied carbon hot spots and build reduction strategies around those; typically slabs and basements (if included) have the highest contributions.
- Design the structure for 100% utilisation where possible. Loading assumptions should be adapted to the building, avoiding rules of thumb and unnecessary tolerances.
- Reduce spans and overhangs, design thinner slabs and lightweight roofs which require less material volume and smaller foundations.
- Incorporate columns within flat layouts and design self-supporting balconies and external walkways.



4 Architectural elements 'lean' design

Façades often represent 15-20% of the upfront embodied carbon emissions in a building.

Considerations to reduce upfront embodied carbon of the building façade include:

- Specifying materials with multiple benefits, e.g. embellishments on the façade that are also used as shading elements.
- Reduce the quantity of metal components: shelf angles, metal studs and frames that make up a large proportion of the total embodied carbon impact.
- Sometimes windows can have a lower upfront embodied carbon than external walls, therefore, make sure not to exceed the recommended glazing-to-walls-ratio (see chapter 2), in order to keep a balance between upfront embodied carbon, the operational energy target (space heating demand), and overheating.

Internal elements are replaced more frequently, and should be considered carefully.

Considerations to reduce upfront embodied carbon of the internal elements include:

- Use self-finishing internal surfaces where appropriate to reduce material volume and maintenance/replacement cost and carbon emissions, e.g. exposed blockwork or concrete in the core of the building.
- Design to standard sizes to reduce waste of materials e.g. design to 600mm stud spacing to accommodate 1,220mm width plasterboard.
- Reduce the quantity of metal studs and frames, due to their high carbon content.

All buildings - building services lean design and low embodied carbon materials

5 Building services low carbon design

Building services have a lower overall impact on upfront embodied carbon than the rest of the building elements. However, they are made from high carbon materials (metals, plastics, refrigerants) which are replaced multiple times during a building's lifetime.

It is important when selecting the appropriate heating system for Net Zero Carbon buildings, the upfront and lifecycle embodied from MEP system are considered. Considerations to reduce upfront and life cycle emissions include:

- Target passive measures e.g. optimised glazing ratios, natural ventilation and shading devices to reduce over-reliance on building services heating and cooling equipment. See section 3.
- Reduce the need for long pipe and duct runs and design for efficiency where possible. See section 3.
- Specify low global warming potential (GWP) refrigerant where feasible and ensure low leakage rate. The UK Net Zero Building Standard (NZCBS) pilot version launched in September 2024, suggests that for all buildings, there should be a GWP limit for refrigerant systems of 677 $kgCO_2e/kg$. This limit corresponds to the current GWP for refrigerant R32. If the GWP value for R32 changes in the future, then the UKNZBS will re-assess the limit.

6 Follow embodied carbon hierarchy for materials and products specification

Materials used in superstructure and substructure are generally used in large quantities, so their selection is likely to have a significant impact on the overall upfront embodied carbon.

Use the embodied carbon hierarchy below to inform material choice particularity for the building structure:

- Natural materials* e.g. timber (lower upfront embodied carbon)
- Concrete and masonry
- Light gauge/Cold rolled steel
- Hot rolled steel (higher upfront embodied carbon)

Prioritise and specify low embodied carbon materials:

- Reused and recovered existing materials from local area or existing building/external works, e.g. reclaimed wood for benches, reclaimed soil and stones and brick for landscape design
- Natural materials from sustainably managed sources*
- Use local materials
- Specify materials with high recycled content
- Specify products which can be recycled e.g. polyester powder coated rather than anodized aluminium

Considerations for selecting products:

- Ask manufacturers for Environmental Product Declarations (EPD) and compare the impacts between products. EPDs produced in accordance with BS EN 15804 (2019) (dated post 2019) are most reliable.
- Consider service life especially for furniture, fixtures, equipment and building services. More robust and long lasting materials will require less maintenance and fewer replacements.
- Specify manufacturers which recover the materials at end of life of the building

* Check specification restrictions due to building's height and/or fire regulations.

All buildings - The importance of natural materials

The importance of natural materials

The significance of using natural materials becomes particularly evident when considering their upfront (modules A1-A5), end of life (modules C1-C4) and beyond life cycle carbon emissions (module D). Wide environmental and health benefits of natural materials include the creation of healthy buildings in terms of indoor air quality and enhancing the breathability of the building.

Some natural building materials come from an abundant source (rammed earth) and others from a regenerative source due to their ability to be re-grown (timber, straw, hemp, bamboo, cork, mycelium). Whereas, synthetic materials like petroleum-based insulation (PIR, phenolic and EPS) come from a finite fossil fuel, which significantly contribute to climate change.

Confusion and conflict can arise where synthetic materials appear lower embodied carbon than natural materials. This can be due to their end of life scenario, such as the incineration of timber. However, we ultimately need to consider the impact of the base materials used (such as fossil fuel oils) in contributing to climate change. Therefore, the selection of materials should first prioritise the use of natural materials while considering embodied carbon emissions and any restrictions due to building's height and/or fire regulations.

The importance of locally sourced materials

Using locally sourced materials, obtained from a defined radius around project sites, promotes sustainability principles by reducing transportation and energy carbon emissions and costs, while supporting local economies. However, it presents challenges such as variability in material quality and limited availability, which can complicate construction planning and increase construction costs.

The use of natural building materials is encouraged to lead to increased market demand and provide opportunities for new businesses and supply chains to develop in response. Additional scale and local supply chains will help to reduce cost as well as transport related emissions while also supporting economic growth within the region.

Broader environmental and health benefits of using natural materials

- **Reduced upfront embodied carbon:** natural materials typically require less energy for extraction, processing, and transportation compared to synthetic materials.
- **End-of-life embodied carbon:** unlike synthetic which end up in landfills, natural materials are often biodegradable or can be easily repurposed, minimizing landfill waste and reducing end-of-life emissions.
- **Enhanced circular economy integration:** natural materials, such as reclaimed wood, can be more effectively upcycled or reused, supporting the principles of the circular economy and reducing overall material waste. In contrast, synthetic materials like PVC often faces challenges in recycling due to contamination and degradation.
- **Improved indoor air quality:** natural materials like wool insulation emit fewer volatile organic compounds (VOCs) compared to synthetic alternatives like spray foam insulation, contributing to healthier indoor environments.
- **Improved building breathability:** natural materials allow for moisture to travel through the building elements, rather than being trapped within the construction, increasing the risk of condensation, mould growth and structural damage.

5

Reduce overheating risk

Building design measures for reduced overheating

The importance of reducing overheating risk

As the climate changes there is a greater risk of overheating in buildings, which can be particularly acute for heavily glazed buildings and homes with vulnerable residents who spend significant proportion of their time at home (e.g. elderly residents or young children). Overheating in buildings is not a stand alone issue, it crosses paths with energy efficiency, daylight, acoustics, air quality, security and safety making it a complex and important design issue.

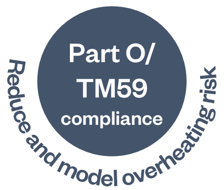
Focus on reducing and then mitigating overheating risk

Designers have the ability to significantly reduce overheating risk through orientation, massing, façade and window design, internal layout and shading.

Minimise overheating risk

Policy JP-S2 seeks to minimise overheating risks. The following methods can be used to demonstrate this.

Residential developments



Demonstrate how overheating risk is reduced through good design. Carry out a Part O assessment and where possible following CIBSE TM59 methodology with alterations, to assess the impact of design measures in mitigating overheating risk.

Non-residential developments

Demonstrate how overheating risk is reduced through good design. Carry out CIBSE TM52 dynamic thermal modelling to assess the impact of design measures in mitigating overheating risk.

Site opportunities and constraints

Consider how location (urban, suburban or rural) and site characteristics (e.g. noise, security, colour of surfaces and green/blue infrastructure) can influence likelihood of overheating. Work within site constraints and introduce measures that reduce the likelihood of overheating.

Massing and site layout

Develop building massing with internal layout in mind, prioritising rooms with larger windows on south façades, where solar gains are easiest to treat. Maximise opportunities for dual aspect dwellings and cross ventilation in buildings.

Designing for acoustics

Noisy surroundings can make overheating mitigation more challenging, determine approaches to window opening and ventilation that work with constraints. Acoustic louvre panels with openings are sometimes used, however, these restrict airflow reducing the effectiveness of the ventilation opening.

Window design

Design using window to wall proportions set out in section 3, to balance solar gain, heat loss, daylight and ventilation. Avoid fixed windows and design for larger openable areas to increase ventilation. Consider how windows might interact with external shading and avoid excessive use of full height glazing.

Shading strategies

Externally shade windows appropriately for their orientation, set out in section 3, without overreliance on solar control glass. Internal blinds provide some shading to reduce heat gains from the sun, but it is not as effective as external shading and is not supported as a solution under Part O building regulations for overheating in homes.

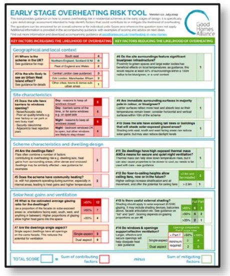
Mechanical ventilation and communal services

Boosting of mechanical ventilation and introduction of active comfort cooling should be a last resort.

Communal heating pipework can contribute to overheating, reduce pipework lengths and insulate pipework to slow heat transfer into spaces.

All buildings - Overheating design guidance *(1/2)*

1 Understand site opportunities and constraints



Use the Good Homes Alliance early stage overheating risk tool to understand the factors that could contribute to or mitigate the likelihood of overheating in dwellings. This includes the role of green and blue infrastructure which can positively affect the local micro-climate. Commission an acoustic assessment/survey to determine site challenges. Aspects of this tool are also applicable to non-residential buildings.

2 Massing and internal layout

Develop building massing with internal layout in mind, prioritising rooms with larger windows on south façades, where solar gains are easiest to treat.

Overheating can be significantly reduced through the following design interventions:

- Maximise dual aspect buildings for effective cross ventilation. Refer to section 3 - dual aspect and cross ventilation.
- Increase the distances from neighbouring overshadowing buildings to maximise natural light and heat gains during winter time. Heat gains during summer time can be mitigated with appropriate shading strategies. Refer to section 3 - solar shading.
- Choose light coloured finishes internally and on balconies/overhangs to ensure maximum daylight reflection within buildings.
- Develop massing to allow rooms which require larger window areas (such as living rooms) to face south. Balconies or fixed external shading can be used as a cost effective way to provide shading to south facing windows.
- East and west-facing windows will typically require movable external shading to mitigate overheating. The size of windows and types of shading devices will therefore become more critical. Avoid bedrooms with west facing windows, this risks bedrooms heating up before residents go to bed, exacerbating night time overheating. If there are bedrooms facing west, avoid large window proportions to reduce overheating risk.

3 Designing for acoustics

Noisy surroundings can make mitigating overheating more challenging.

- Where acoustic issues exist, work with the acoustic engineer and use the Acoustics and Noise Consultants (ANC) Acoustics, Ventilation and Overheating Guide to determine approaches to window openings and ventilation.
- Where it is determined that windows cannot be opened for extended periods of time, due to excess noise, it is critical to integrate the following into the design:
  - Window sizes appropriate for orientation
  - Adequate shading per window and orientation
  - Passive ventilation strategies such as cross ventilation and acoustically attenuated opening panels.
- Only once the above has been optimised should boosted mechanical ventilation or tempered air be considered. Comfort cooling should be an absolute last resort in homes and the cooling demand should already be reduced through good building design.

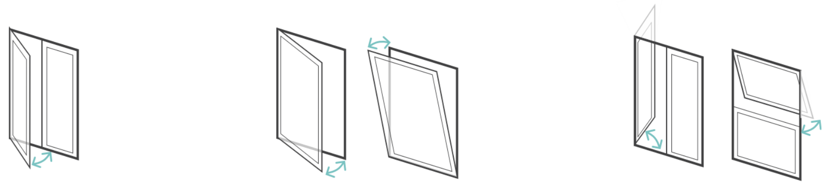
All buildings - Overheating design guidance *(2/2)*

4 Window design

Window design plays a significant role in overheating risk as their size and position influence the amount of solar heat gain and natural ventilation.

- Design window proportions to suit orientation. Refer to Chapter 2, elevations to balance heat gain, heat loss and daylight.
- Avoid fixed windows (non-openable) and design window fenestration to maximise openable areas of windows. Side hung windows typically allow more ventilation than top hung. Window opening types should be considered alongside local context.
- Specify inward opening windows to allow the operation of external shading in combination with window opening. Consider how this interacts with layout of furniture and fittings (e.g. windows clashing with kitchen taps).
- For dwellings, begin with a g-value of 0.5 (offices 0.3-0.4, schools and industrial 0.4-0.5) for glass to balance heat gain and loss. G-values lower than 0.5 can reduce overheating but also have an adverse effect on winter solar gains, particularly in homes. Aim to only alter the g-value as a response to remaining overheating risk once window size and shading has been taken into account.
- Avoid floor to ceiling windows, unless necessary (such as, onto balconies. A sill height below 800mm has little benefit to daylight, whereas, it increases the overheating risk.

Types of window openings



Side-hung inward opening
Maximised opening areas and allow for external shading to be fitted without clashes. Smaller pane sizes reduce clashes with internal furniture.

Tilt and turn inward opening
Maximum opening areas and allow for external shading to be fitted without clashes. Added benefit of secure night opening with tilt function. Larger panes may clash with internal furniture.

Side and top hung outward opening
Side hung is more effecting at ventilation than top hung as the window can often be opened wider. Outward opening windows prevent the installation of external shutters.

5 Shading strategies

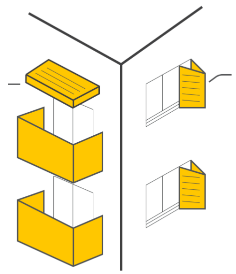
Shading can significantly reduce the overheating risk.

- Where windows face south, include fixed external shading above windows, such as brise soleil, stacked balconies (with shading for the top floor) or deep reveals or movable external shading.
- Where windows face east or west, include movable external shading to shade the full height of windows, such as shutters and louvres.
- Even though internal shading can reduce solar heat gains, avoid relying on internal blinds or curtains, which can be removed or changed by occupants. Closed blinds should not be relied on to reduce overheating.
- Use Good Homes Alliance Shading for Housing guide for the effect and use of specific shading strategies on UK projects.

Types of window shading

South-facing façades

Balconies with additional shading for the top floor, or brise soleil



East/west-facing façades

Moveable external shutters for east and west façades

6 Mechanical equipment and communal spaces

Mechanical solutions should be the last resort in minimising overheating risk. Communal spaces served by communal/district heating are more vulnerable to overheating.

- Boosting of mechanical ventilation, using tempered air supply and finally comfort cooling should only be considered when passive strategies from steps 2-5 are found insufficient in preventing and removing excess heat.
- Reduce heating/hot water pipe runs in corridors following CP1 guidance and insulate pipes to slow the heat from pipes entering corridors.

6

Case studies

Case studies - low-rise housing

Examples of existing buildings in England that meet some of the Net Zero key performance indicators.

KEY: ✓ Key performance indicator (KPI) has been met ✗ KPI not met

Image source: Google maps

Brassington Avenue, Salford, Manchester

Building typology: terrace houses
Architect: PRP Architects
Total number of dwellings on site: 3
Completion: 2021

Net Zero design strategies:

- High performance fabric
- Simplified design form
- Optimised glazing areas to orientation
- Fossil fuel free

Performance against Net Zero requirements:

✓ 16 kWh/m2/year – Space heating demand

Exterior wall U-value: 0.11 W/m^{2}K
Ground floor U-value: 0.09 W/m^{2}K
Roof U-value: 0.08 W/m^{2}K
Window U-value: 1.01 W/m^{2}K
Window g-value: 0.58
Air permeability: 0.60 ac/h

Fossil fuel free | EUI: ? kWh/m^2.yr | ✗ Net Zero (Net Zero Balance) | Certified PH

Image source: Phi Architects

Mawdesley, Lancashire

Building typology: detached house
Architect: Phi Architects
Total number of dwellings on site: 1
Completion: 2017

Net Zero design strategies:

- High performance fabric
- Optimised glazing areas to orientation

Performance against Net Zero requirements:

✓ 14 kWh/m2/year – Space heating demand

Exterior wall U-value: 0.16 W/m^{2}K
Ground floor U-value: 0.10 W/m^{2}K
Roof U-value: 0.13 W/m^{2}K
Window U-value: 0.90 W/m^{2}K
Window g-value: 0.47
Air permeability: 0.37 ac/h

Uses fossil fuels | EUI: ? kWh/m^2.yr | ✗ Net Zero (Net Zero Balance) | Certified PH

Image source: RP Tyson Construction

Ince St Marys, Wigan

Building typology: semi detached and terraced housing
Architect: Pozzoni Architecture
Total number of dwellings on site: 47
Completion: 2024

Net Zero design strategies:

- High performance fabric
- Fossil fuel free
- Simplified Design form
- Optimized glazing areas
- Renewable energy generated on site

Performance against Net Zero requirements:

✓ 15 kWh/m2/year – Space heating demand

Exterior Wall U value – 0.11 W/m²K
Ground floor U value - 0.12 W/m²K
Roof U Value - 0.08 W/m²K
Window U value – 0.90 W/m²K
Window g-value – 0.55
Air permeability –0.60 ac/h max

Fossil fuel free | EUI: ? kWh/m^2.yr | ✗ Net Zero (Net Zero Balance) | Certified PH

Image source: Levitt Bernstein

Blackrock Street, Manchester

Building typology: semidetached houses
Architect: GWP Architecture
Total number of dwellings on site: 2 (22)
Completion: 2022

Net Zero design strategies:

- High performance fabric
- Simplified design form
- Optimised glazing areas to orientation
- Fossil fuel free
- Renewable energy generated on site

Performance against Net Zero requirements:

✓ 15 kWh/m2/year – Space heating demand

Exterior wall U-value: 0.12 W/m^{2}K
Ground floor U-value: 0.09 W/m^{2}K
Roof U-value: 0.09 W/m^{2}K
Window U-value: Unknown
Window g-value: Unknown
Air permeability: 0.60 ac/h

Fossil fuel free | EUI: ? kWh/m^2.yr | ✓ Net Zero (Net Zero Balance) | Certified PH

Case studies - low and mid-rise apartments

Examples of existing buildings in England that meet some of the Net Zero key performance indicators.

KEY: ✓ Key performance indicator (KPI) has been met ✗ KPI not met

Image source: Buttress Architects

Greenhaus, Salford, Greater Manchester

Building typology: mid-rise block of flats

Architect: Buttress Architects

Total number of dwellings on site: 96

Completion: 2024

Net Zero design strategies:

- High performance fabric
- Simplified design form
- Optimised glazing areas
- Heat pump for hot water

Performance against Net Zero requirements:

✓ 15 kWh/m2/year Space heating demand

Exterior wall U-value: 0.26 W/m^{2}K
Ground floor U-value: 0.15 W/m^{2}K
Roof U-value: 0.17 W/m^{2}K
Window U-value: 0.81 W/m^{2}K
Window g-value: 0.35
Air permeability: 0.50 ac/h

Fossil fuel free | ? kWh/m^2.yr EUI | ✗ Net Zero Balance — Net Zero | Certified PH

Image source: PRP Architects

Clifton Green, Salford, Manchester

Building typology: low-rise block of flats

Architect: PRP Architects

Total number of dwellings on site: 19

Completion: 2022

Net Zero design strategies:

- High performance fabric
- Simplified design form
- Optimised glazing areas to orientation
- Fossil fuel free

Performance against Net Zero requirements:

✓ 16 kWh/m2/year Space heating demand

Exterior wall U-value: 0.19 W/m^{2}K
Ground floor U-value: 0.14 W/m^{2}K
Roof U-value: 0.10 W/m^{2}K
Window U-value: 1.11 W/m^{2}K
Window g-value: 0.58
Air permeability: 0.90 ac/h

Fossil fuel free | ? kWh/m^2.yr EUI | ✗ Net Zero Balance — Net Zero | Low energy house

Image source: Levitt Bernstein

Plashet Road, Newham, London

Building typology: mid-rise block of flats

Architect: Levitt Bernstein

Total number of dwellings on site: 65

Completion: 2024

Net Zero design strategies:

- High performance fabric
- Simplified design form
- Optimised glazing areas to orientation
- Fossil fuel free

Performance against Net Zero requirements:

✓ 15 kWh/m2/year Space heating demand

Exterior wall U-value: 0.15 W/m^{2}K
Ground floor U-value: 0.11 W/m^{2}K
Roof U-value: 0.10 W/m^{2}K
Window U-value: 1.16 W/m^{2}K
Window g-value: 0.53
Air permeability: 0.60 ac/h

Fossil fuel free | 43 kWh/m^2.yr EUI *(non TANZ compliant)* | ✗ Net Zero Balance — Net Zero | Certified PH

Image source: Virtual Planit

Oldfield Basin, Salford, Greater Manchester

Building typology: low-rise block of flats

Architect: Feilden Clegg Bradley Studios

Total number of dwellings on site: 90

Completion: planning permission granted

Net Zero design strategies:

- South-facing orientation
- Simplified design form – long terrace
- Optimised glazing areas

Design against Net Zero requirements:

✓ 13 kWh/m2/year Space heating demand

Exterior wall U-value: 0.13 W/m^{2}K
Ground floor U-value: 0.11 W/m^{2}K
Roof U-value: 0.12 W/m^{2}K
Window U-value: Unknown
Window g-value: Unknown
Air permeability: Unknown

Uses fossil fuel | 40 kWh/m^2.yr EUI *(non TANZ compliant)* | ✗ Net Zero Balance — Net Zero | Design

Case studies - offices

Examples of existing buildings in England that meet some of the Net Zero key performance indicators.

KEY: ✓ Key performance indicator (KPI) has been met ✗ KPI not met

Image source: Swann Edwards Architecture

Black Barns Office, Guyhirn, Wisbech

Building typology: office
Architect: Swann Edwards Architecture
Completion: 2018

Net Zero design strategies:

- Simplified design form
- Optimised glazing areas to orientation
- Solar shading strategy

Performance against Net Zero requirements:

✓ 11 kWh/m2/year Space heating demand

Exterior wall U-value: 0.13 W/m^{2}K
Ground floor U-value: ≤0.11 W/m^{2}K
Roof U-value: 0.12 W/m^{2}K
Window U-value: 0.7 W/m^{2}K
Air permeability: 0.4 ac/h

Uses fossil fuels | ? kWh/m^2.yr EUI | ✗ Net Zero Balance Net Zero | Certified PH

Image source: CPMG Architects

Interserve Office, Syston, Leicester

Building typology: office
Architect: CPMG
Completion: 2011

Net Zero design strategies:

- Simplified design form
- Optimised glazing areas to orientation
- Fossil fuel free
- Renewable energy generated on-site

Performance against Net Zero requirements:

✓ 13 kWh/m2/year Space heating demand

Exterior wall U-value: 0.11-0.12 W/m^{2}K
Ground floor U-value: 0.13 W/m^{2}K
Roof U-value: 0.13 W/m^{2}K
Window U-value: 0.80 W/m^{2}K
Air permeability: 0.44 ac/h

Fossil fuel free | ? kWh/m^2.yr EUI | ✗ Net Zero Balance Net Zero | Certified PH

Image source: Architype

Bicester Eco Business Centre, Bicester

Building typology: co-working spaces
Architect: Architype
Completion: 2018

Net Zero design strategies:

- Simplified design form
- Optimised glazing areas
- Solar shading strategy
- Renewable energy generated on-site

Performance against Net Zero requirements:

✓ 13 kWh/m2/year Space heating demand

Exterior wall U-value: 0.15 W/m^{2}K
Ground floor U-value: 0.11 W/m^{2}K
Roof U-value: 0.10 W/m^{2}K
Window U-value: <1.00 W/m^{2}K
Window g-value: 0.53
Air permeability: 0.59 ac/h

Uses fossil fuels | ? kWh/m^2.yr EUI | ✓ Net Zero Balance Net Zero | Certified PH Plus

Image source: Alchemilla Architects

Payhembury, Devon

Building typology: office
Architect: Alchemilla Architects
Completion: 2017

Net Zero design strategies:

- Optimised glazing areas to orientation
- Fossil fuel free
- Renewable energy generated on-site

Performance against Net Zero requirements:

✓ 12 kWh/m2/year Space heating demand

Exterior wall U-value: 0.12 W/m^{2}K
Ground floor U-value: 0.11 W/m^{2}K
Roof U-value: 0.09 W/m^{2}K
Window U-value: 0.85 W/m^{2}K
Window g-value: 0.54
Air permeability: 0.60 ac/h

Fossil fuel free | ? kWh/m^2.yr EUI | ✗ Net Zero Balance Net Zero | Certified PH

Case studies - schools

Examples of existing buildings in England that meet some of the Net Zero key performance indicators.

KEY: ✓ Key performance indicator (KPI) has been met ✗ KPI not met


Image source: Space Architects

Richmond Hill Primary School, Leeds

Building typology: primary school
Architect: Space Architects
Completion: 2012

Net Zero design strategies:

- Simplified design form
- Optimised glazing areas

Performance against Net Zero requirements:

✓ 11 kWh/m2/year — Space heating demand

Exterior wall U-value: 0.11 W/m²K
Ground floor U-value: 0.06 W/m²K
Roof U-value: 0.07 W/m²K
Window U-value: 0.97 W/m²K
Window g-value: 0.64
Air permeability: 0.25 ac/h

Uses fossil fuels | ? kWh/m²yr EUI | ✗ Net Zero Balance — Net Zero | Certified PH

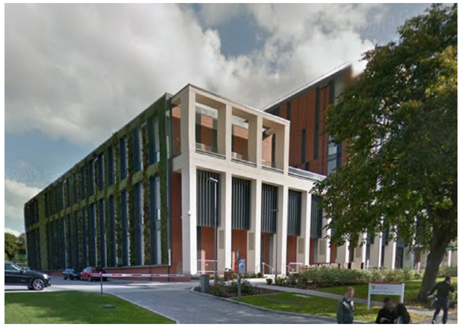


Image source: Google Maps

Centre of Medicine, University of Leicester

Building typology: university
Architect: Associated Architects
Completion: 2016

Net Zero design strategies:

- High performance fabric
- Simplified main body design form
- Optimised glazing areas to orientation
- Fossil fuel free
- Solar shading strategy

Performance against Net Zero requirements:

✓ 15 kWh/m2/year — Space heating demand

Exterior wall U-value: 0.13 W/m²K
Ground floor U-value: 0.25 W/m²K
Roof U-value: 0.13 W/m²K
Window U-value: 0.75 W/m²K
Window g-value: 0.48
Air permeability: 0.34 ac/h

Fossil fuel free | ? kWh/m²yr EUI | ✗ Net Zero Balance — Net Zero | Certified PH


Image source: Leigh Simpson

Oakmeadow Primary School, Wolverhampton

Building typology: primary school
Architect: Architype
Completion: 2011

Net Zero design strategies:

- High performance fabric
- Simplified design form
- Optimised glazing areas to orientation
- Solar shading strategy
- Natural cross ventilation

Performance against Net Zero requirements:

✓ 15 kWh/m2/year — Space heating demand

Exterior wall U-value: 0.13 W/m²K
Ground floor U-value: 0.14 W/m²K
Roof U-value: 0.11 W/m²K
Window U-value: 0.95 W/m²K
Window g-value: 0.46
Air permeability: 0.48 ac/h

Uses fossil fuels | ? kWh/m²yr EUI | ✗ Net Zero Balance — Net Zero | Certified PH


Image source: Christian Trampenau Photographer

Thornhill Primary School, Bedfordshire

Building typology: primary school
Architect: ECD Architects
Completion: 2022

Net Zero design strategies:

- High performance fabric
- Simplified design form
- Optimised glazing areas to orientation
- Solar shading strategy

Performance against Net Zero requirements:

✓ 15 kWh/m2/year — Space heating demand

Exterior wall U-value: 0.07-0.14 W/m²K
Ground floor U-value: 0.11 W/m²K
Roof U-value: 0.06-0.11 W/m²K
Window U-value: 0.88 W/m²K
Window g-value: 0.50
Air permeability: 0.42 ac/h

Uses fossil fuels | 62 kWh/m²yr EUI | ✗ Net Zero Balance — Net Zero | Certified PH

7

Appendix

Glossary of terms

Air permeability – *'The measure of airtightness of the building fabric. It is defined as the air leakage rate per hour per m2 of envelope area at the test reference pressure differential of 50Pa or 4Pa.'* Source: Building Regulations Part L

Airtightness – *The resistance of the building envelope to infiltration when ventilators are closed. The greater the airtightness at a given pressure difference across the envelope, the lower the infiltration.'* Source: Building Regulations Part L

Biogenic/ sequestered carbon – *'Carbon removals associated with carbon sequestration into biomass, as well as any emissions associated with this sequestered carbon. Biogenic carbon must be reported separately if reporting only upfront carbon, but should be included in the total if reporting embodied carbon or whole life carbon.'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

Capacity – The capacity of the system is the maximum power output. It depends on the installation's size and technical capability. The capacity may be in terms of electrical or thermal output.

Carbon sequestration – *'The process by which CO2 is removed from the atmosphere and stored within a material, for example by being stored in biomass as biogenic carbon by plants.'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

Chartered Institute of Building Services Engineers (CIBSE) TM52 - '*This Technical Memorandum (TM) is about predicting overheating in buildings. It is intended to inform designers, developers and others responsible for defining the indoor environment in buildings. It includes the recommendations of the Overheating Task Force, which has sponsored and published this document.'* Source: CIBSE

Chartered Institute of Building Services Engineers (CIBSE) TM59 methodology - *'The application of this technical memorandum, by standardising the assessment methodology, should play a key role in limiting overheating risk in new and refurbished homes.'* Source: CIBSE

Chartered Institute of Building Services Engineers (CIBSE) TM65 methodology - '*A calculation methodology (TM65) outlines the need for assessment of embodied carbon of products linked to building services engineering systems, to increase knowledge and facilitate research related to whole life carbon.'* Source: CIBSE

Combined heat and power – A system which generates electricity whilst also capturing usable heat generated in the process. Typically, when referring to CHP it is inferred that this is gas-fired though this does not necessarily need to be the case.

Deep retrofit – '*Development involving the re-use of as much of the existing building as possible, but may involve substantial demolition and replacement of parts of (but not all of) the façade, core, floor and slab, and which results in significant energy, performance, and climate adaptation upgrades, comparable to those a new building, dramatically reducing carbon emissions from the building and prolonging its usable lifespan.*' Source: Westminster City Plan Retrofit first Topic Paper, City Plan 2024.

Demolish and recycle - *'Traditional demolition, with elements and materials processed into new elements, materials and objects for use on the site or on another site.'* Source: CE Statement 2022.

Disassemble and reuse - '*Disassemble sections of a building and enable their direct reuse ideally on the site or, where this is not possible, off site (with nearby sites preferred). This approach also includes careful selective deconstruction of the building and material types i.e. taking apart each layer and material type as much as possible, minimising damage to parts and maintaining their value, and then reusing those elements and materials. If reuse is not possible, materials may be carefully and selectively separated for processing and recycling into new elements, materials and objects.*' Source: CE Statement 2022.

Embodied carbon – '*The embodied carbon emissions of an asset are the total GHG emissions and removals associated with materials and construction processes, throughout the whole life cycle of an asset (modules A0–A5, B1–B5, C1–C4, with A0[2] assumed to be zero for buildings.'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

Energy Use Intensity (EUI) – *'An annual measure of the total energy consumed in a building ... 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.'* Source: LETI

Environmental Product Declaration (EPD) – *'A document that clearly shows the environmental performance or impact of any product or material over its lifetime.'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

Form factor – *'Form factor measures how compact a building is and how well it retains heat. It is a ratio of external fabric area to internal area.*

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.'* Source: LETI

Glossary of terms

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.'* Source: LETI

Global warming potential (GWP) – The Global Warming Potential of a refrigerant is often expressed in carbon dioxide equivalents (CO2e). The timescale the value refers to may be in the order of 50 or 100 years.

Gross Internal Area – *'Broadly speaking the whole enclosed area of a building within the external walls taking each floor into account and excluding the thickness of the external walls.'* Source: gov.uk

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.'* Source: LETI

Heat Pump – A heat pump is a device that transfers thermal energy from a heat source to a heat sink (e.g. the ground to a house). There are many varieties of heat pump e.g. air, ground and water source heat pumps. The first word in the title refers to the heat source from which the pump draws heat. The pumps run on electricity, however less energy is required for their operation than they generate in heat, hence their status as a renewable technology.

Inventory of carbon & energy (ICE) database – *'The Inventory of Carbon and Energy (also know as the ICE database) is an embodied carbon database for building materials which is available for free on this page. It contains data for over 200 materials, broken down into over 30 main material categories.'* Source: ICE

Kilowatt – Unit of power equivalent to a thousand watts.

Kilowatt hour – Unit of energy. It is equal to the amount of energy a system will generate in an hour whilst running at a kilowatt power output.

Life Cycle embodied carbon – *See 'embodied carbon'*

Major development – *'Major development is: for housing, development where 10 or more homes will be provided, or the site has an area of 0.5 hectares or more [OR] The provision of a building or buildings where the floor space to be created by the development is 1,000 square metres or more [OR] Development carried out on a site having an area of 1 hectare or more.'* Source: gov.uk

Major renovation – *'Defined in regulation 35 as the renovation of a building where more than 25% of the surface area of the building envelope undergoes renovation.'* Source: Approved Document Part L 2021.

Megawatt – Unit of power equivalent to a million watts

Megawatt hour – Unit of energy. It is equal to the amount of energy a system will generate in an hour whilst running at 1 megawatt power output.

Minor development – *'Minor non-residential extensions (industrial/commercial/leisure etc): extensions with a floorspace not in excess of 250 square metres [OR] Alterations: development that does not increase the size of buildings, e.g. alterations to external appearance [OR] Householder development: for example, sheds, garages, games rooms etc. within the curtilage of the existing dwelling, in addition to physical extensions to the existing dwelling itself. This definition excludes any proposed development that would create a separate dwelling within the curtilage of the existing dwelling (e.g. subdivision of houses into flats) or any other development with a purpose not incidental to the enjoyment of the dwelling.'* Source: gov.uk

Offsetting – *'Payment to receive credit for a certified unit of carbon emission reduction or removal carried out by another actor. Varying levels of accreditation exist for carbon offsets.'* Source: UK Net Zero Carbon Buildings Standard

Operational carbon – *'Operational carbon – energy (module B6) refers to GHG emissions arising from all energy consumed by an asset in use, over its life cycle.'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

Overheating – *'Refers to discomfort to occupants caused by the accumulation of warmth within a building.'* Source: The Construction Wiki

Partial retention and refurbishment – '*Significant quantities of carbon-heavy aspects of the building are retained in place, such as the floors and substructure, with replacement of some elements of the building, such as walls or roofing. More significant refurbishment can involve adding floors or extensions.'* Source: CE Statement 2022

Passivhaus planning package (PHPP) – Predictive energy modelling tool, typically used for Passivhaus projects, but can be used for any project to better predict performance and deliver outcomes.

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.'* Source: LETI

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

Photovoltaics (PV) – solar panels converting sunlight into electricity.

Glossary of terms

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: RIBA

Regulated energy – *'Regulated energy is building energy consumption resulting from the specification of controlled, fixed building services and fittings, including space heating and cooling, hot water, ventilation, fans, pumps and lighting. Such energy uses are inherent in the design of a building.'* Source: The Construction Wiki

Renewable energy – *'Renewable energy technologies use natural energy sources to generate electricity and/or heating/cooling. Sources include solar, wind, wave, marine, hydro, etc.'* Source: LETI, 2nd edition

Responsible retrofit – *'Responsible retrofitting is an informed and integrated attitude to retrofit in a way that enables people to reduce the operational carbon of a building, improve energy efficiency, and/or improve a building's resilience to the impacts of climate change. Responsible retrofit will take into account the building's location, context, design, construction, materials and use, to ensure retrofit measures perform well and avoid adverse impacts to health, heritage and the natural environment.'* Source: Westminster City Plan Retrofit first Topic Paper, City Plan 2024.

Retain and retrofit - *'The vast majority of the building's fabric is retained, with the building refurbished for the same or new uses through restoring, refinishing and future-proofing. This also encompasses retrofitting, where new technology or features are added to existing buildings to make them more efficient and to reduce their environmental impacts.'* Source: Circular Economy (CE) Statement 2022.

Retrofit – *'Development involving the re-use of at least 50% of the existing building in-situ (by mass or volume), retaining as a minimum the foundations, core, and floor slabs, and which results in energy, performance, and climate adaptation upgrades, which will reduce carbon emissions from the building and prolong its usable lifespan.'* Source: Westminster City Plan Retrofit first Topic Paper, City Plan 2024.

RICS Professional Standard (RICS PS v2 2023)– *'Sets requirements or expectations for RICS members and regulated firms about how they provide services or the outcomes of their actions. RICS professional standards are principles-based and focused on outcomes and good practice. Any requirements included set a baseline expectation for competent delivery or ethical behaviour. They include practices and behaviours intended to protect clients and other stakeholders, as well as ensuring their reasonable expectations of ethics, integrity, technical competence and diligence are met. Members must comply with an RICS professional standard.'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

Substantial demolition – *'Development consisting of the demolition of 50% or more of existing above ground structures, by area or volume, but not constituting total demolition.'* Source: Westminster City Plan Retrofit first Topic Paper, City Plan 2024.

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).'* Source: LETI

Total demolition – *'The removal, deconstruction or demolition of an existing building, which will entail the removal of all of its fit out, superstructure, cores, and basement slab(s), but which could involve the retention of parts or all of the façade.'* Source: Westminster City Plan Retrofit first Topic Paper, City Plan 2024.

Unregulated energy – *'Unregulated energy is building energy consumption resulting from a system or process that is not 'controlled', i.e. energy consumption from systems in the building on which the Building Regulations do not impose a requirement. For example, this may include energy consumption from systems integral to the building and its operation, e.g. IT equipment, lifts, escalators, refrigeration systems, external lighting, ducted-fume cupboards, servers, printers, photocopiers, laptops, cooking, audio-visual equipment and other appliances.'* Source: The Construction Wiki

Upfront embodied carbon – *'Upfront carbon emissions are GHG emissions associated with materials and construction processes up to practical completion (modules A0–A5). Upfront carbon excludes the biogenic carbon sequestered in the installed products at practical completion.'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

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.'* Source: LETI

Whole life carbon (WLC) - *'Whole life carbon emissions are the sum total of all asset-related GHG emissions and removals, both operational and embodied, over the life cycle of an asset, including its disposal (modules A0–A5, B1–B7, B8 optional, C1–C4, all including biogenic carbon, with A0[2] assumed to be zero for buildings). Overall whole life carbon asset performance includes separately reporting the potential benefits or loads from future energy or material recovery, reuse, and recycling and from exported utilities (modules D1, D2).'* Source: RICS Whole life carbon assessment for the built environment, 2nd edition

Abbreviations

AHU: Air Handling Unit

ASHP: Air Source Heat Pump

CHP: Combined Heat and Power

CIBSE: Chartered Institution of Building Services Engineers

CLT: Cross Laminated Timber

CO_2e: Carbon dioxide equivalent

DHW: Domestic Hot Water

EAHP: Exhaust Air Heat Pump

EC: Embodied Carbon

EPD: Environmental Product Declaration

EUI: Energy Use Intensity

GIA: Gross Internal Area

HP: Heat Pump

GGBS: Ground Granulated Blast-furnace Slag

GHG: Greenhouse gas

GWP: Global warming potential

IPCC: Intergovernmental Panel on Climate Change

IStructE: Institution of Structural Engineers

kW: Kilowatt

kWh: Kilowatt hour

KPI: Key performance indicator

LETI: Low Energy Transformation Initiative

MEP: Mechanical, electrical and plumbing

MVHR: Mechanical Ventilation with Heat Recovery

MW: Megawatt

MWh: Megawatt hour

NZCBS: UK Net Zero Carbon Buildings Standard

PH: Passivhaus

PHPP: Passivhaus Planning Package

POE: Post-Occupancy Evaluation

PV: Photovoltaic

RIBA: Royal Institute of British Architects

RICS: Royal Institute of Chartered Surveyors

RICS PS: RICS Professional Statement

UKGBC: The UK Green Building Council

UPVC: Unplasticized Polyvinyl Chloride

WLC: Whole life carbon OR whole life cycle

Useful links

- BAMB –Building as material passports
- BECD – Built Environment Carbon Database
- Building to net zero: costing carbon in construction: Government Response to the Committee's First Report – Environmental Audit Committee
- CIRCuIT
- Climate action tracker 2023
- Climate Change Committee - the sixth carbon budget
- CWCT– How to calculate embodied carbon of facades
- Easi Guide Passivhaus Design
- European Union's Roadmap for Whole Life Carbon
- Greencore Homes – low carbon offsite construction
- IStructE How to calculate embodied carbon 2nd edition
- IStructE Lean design: 10 things to do now
- LETI Circular economy 1 pager
- LETI Climate emergency design guide
- LETI Embodied Carbon Primer
- LETI opinion piece - Circular economy and carbon in construction
- LETI opinion piece – operational carbon in whole life carbon assessments
- LETI The Whole Life Carbon Alignment paper
- Net Zero Carbon Toolkit
- Net Zero Carbon Building Standard Pilot
- Net Zero: The UK's Contribution to Stopping Global warming
- Part B building Regulations Volume 1: Domestic
- Part Z proposed amendment to building regulations
- Policy paper by Part Z group of experts , January 2024
- Places for Everyone - Joint development plan document for Bolton, Bury, Manchester, Oldham, Rochdale, Salford, Tameside, Trafford and Wigan
- RIBA 2030 climate challenge
- RICS Whole Life Cycle assessment 2017, 1st edition
- RICS Whole Life Cycle Assessment 2023, 2nd edition
- Services Guide - Zero Carbon Hub
- Shading for housing - Design guide for a changing climate
- The concrete centre– Sustainable concrete
- The construction material pyramid
- Thermal Bridging Guide - Zero Carbon Hub
- TM52 - The limits of thermal comfort: avoiding overheating
- TM54 - Evaluating operation energy use at the design stage
- TM59 - Design methodology for the assessment of overheating risk in homes
- TM65 - Embodied carbon in building services
- UK Net Zero Carbon Building Standard - Pilot
- UKGBC - Circular economy guidance for construction clients
- UKGBC - Circular economy metrics for buildings
- UKGBC – Net zero whole life carbon technical study
- Understanding overheating - where to start - NHBC

Accessibility information

GMCA acknowledges that this guidance is not fully accessible as it would be a disproportionate burden to do so, particularly as it is extremely technical, contains a high number of illustrations and tables, and is used by a low number of people.

Please contact planningandhousing@greatermanchester-ca.gov.uk if you require an accessible version of this document. GMCA will consider your request and aim to get back to you within seven working days.

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