Herefordshire Council

Building Performance

ARCHITYPE

Building Performance Overview

In this section

This section will detail:

1 / How building performance affects energy + emissions

2 / The benefits of re-use or adaption

3 / How ‘passive design’ can help your project

4 / How a fabric-first approach can save energy and improve building performance

5 / How to create healthy + comfortable internal environments through building design.

5 / Embodied carbon is and how to reduce it

6 / Considerations when extending your home, and working with historic buildings

Executive summary

> Reducing a building’s energy demand should be a top priority, before efficiency measures and renewable generation.

> The better a building performs, the easier it is to achieve net zero emissions. Passive design, and a fabric-first approach are the most effective ways of delivering outstanding building performance, and low running costs.

> Factors like orientation, and appropriate ventilation and glazing strategies are key to providing a healthy, comfortable internal environment whilst reducing carbon.

> The embodied carbon used in the manufacture, transport and construction of a building must be minimised as much as possible, and properly accounted for.

Introduction

The UK - and Herefordshire - are in a climate emergency, requiring an urgent reduction in carbon emissions. With buildings in the UK contributing to 49% of the annual carbon emissions *(LETI)*, it is now more important than it has ever been to reduce and eventually eliminate this contribution, with all scales of development having an important role in enabling this to happen.

Carbon emissions from buildings can be attributed to two main areas:

1. the energy required to operate the building (operational carbon), including energy used to heat the building
2. the carbon associated with the building construction (embodied carbon), including the extraction and processing of materials, energy consumption in production, assembly and construction of the building. It also includes the 'in-use' stage (maintenance, replacement etc) through to 'end of life' stage (demolition, disassembly and disposal).

The chapters in this document are ordered in a way that follows a typical design process when considering a development.

When designing a building it is important to also consider the internal environment that is created, and this chapter explains the potential for overheating and actions to minimise this risk along with internal ventilation options and material choices to facilitate a healthy and comfortable internal environment.

This first chapter discusses the performance of a building and addresses the topics covered in Core Strategy policies SD1, SS6 and SS7, specifically related to design to reduce carbon emissions and efficient use of resource. Resilience to climate change, the efficient use of land and utilising passive design are also key themes within these policies and discussed in this chapter.

These topics are expanded upon with the inclusion of the fabric-first, Passivhaus approach to design.

The topic of retention and adaption is particularly relevant to Core Strategy policy LD4, and also when the approach to historic buildings is discussed later in the chapter.

Finally embodied carbon must also be discussed as early design decisions can impact greatly on this.

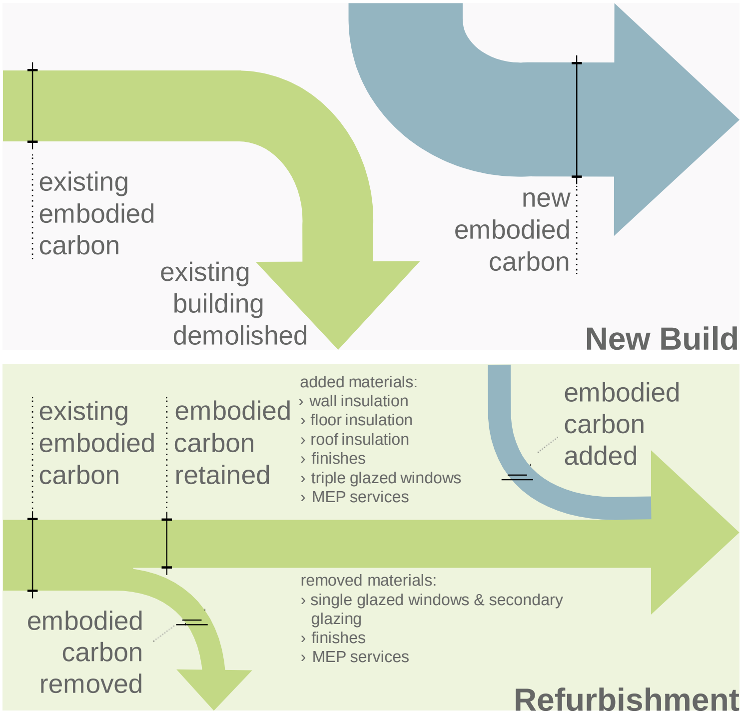
Policies

- Policy SS6 Environmental quality & local distinctiveness
- Policy SS7 Addressing climate change
- Policy SD1 Sustainable design and energy efficiency
- Policy LD4 Historic Environment and Heritage Assets

Most of the following pages discuss best practice for creating healthy, low carbon buildings. However,t he building with the lowest carbon impact is the one that is already built. The next two pages detail why you should first consider retention and adaption on your project.

Retention and Adaption

Worldwide, the construction industry consumes almost all the planet's cement, 26 per cent of aluminium output, 50 per cent of steel production and 25 per cent of all plastics (*Architects Journal: Retro First*). Approximately 49% of the UK's carbon emissions are attributable to the built environment *(LETI)*, while construction, demolition, and excavation activities generate approximately 62% of the UK's waste. *(DEFRA)*



11 **Image 12**:
Embodied Carbon: New Build v's Refurbishment

Definitions

- **Embodied Carbon:** refers to carbon dioxide equivalent emitted during the manufacture, transport and construction of building materials, together with end of life emissions.

Best Practice Recommendations

- Prioritise the refurbishment and retrofit of existing buildings where possible. Also, aim to re-use elements of existing buildings if at all possible, for example foundations (subject to structural engineer input), bricks or even floorboards for a new purpose.

Further Information

- National Design Guide, Ministry of Housing, Communities and Local Government (2021)
- Circular Economy Statement Guidance, Draft for Consultation (2020)
- DEEP DIVE: The choice between demolition or reuse: developer insights, UKGBC

When an existing building is demolished and a new building built as a replacement, the emissions sealed in the original building, referred to as **embodied energy/carbon** are wasted. The construction and material manufacturing required for the new building then create new carbon emissions and so repurposing existing buildings has a large part to play in reducing the UK's carbon emissions, the embodied carbon within buildings and consumption of resources.

Before new development begins consideration should be given to whether existing buildings either on or off site can instead be developed as an alternative.

Image 13: 12 Retrofitting Twyford Barn ©Architype

Fundamentally to do this the brief requirements for the project need to be reviewed and consideration given to whether an existing building could meet these, or if the brief can adapt to suit the building. Quite often financial implications, along with the physical condition of the existing building are large factors in this decision along with the sustainability requirements. However, with an increasing need for buildings to achieve **Net Zero Carbon** and the **circular economy** vision, this can lead to retention and adaptation being not only the most environmentally and socially sustainable solution but also the most financially viable.

Benefits:

- Reduced embodied carbon impact
- Minimises demolition waste and new resource depletion
- Often a less controversial development, that conserves and enhances existing places and neighbourhoods
- Reduces disruption to local neighbourhood from construction works, e.g. noise and dust, leading to better community relationships
- Reduced construction traffic impacts
- Cost and programme savings, depending on the scope of refurbishment
- Phased refurbishment could allow parts of the asset to remain in operation

Definitions

- **Net Zero Carbon:** achieving a balance between the carbon (carbon in this instance refers to CO2e, or 'carbon dioxide equivalent', which means other greenhouse gases are also taken into account) emitted into the atmosphere and the carbon removed from it. This balance will happen when the amount of carbon we add to the atmosphere is no more than the amount removed.
- **Circular Economy:** refers to a regenerative economic system aimed at continual use of resources to eliminate waste. This contrasts the traditional linear economic system: 'take, make, dispose.'

If retention and adaptation is not viable, recovery of the building elements and materials from the existing building should still be considered, contributing to circular economy goals.

Retrofit

In some instances for example when working with historic buildings or with existing housing stock demolition is not possible. In these cases a retrofit strategy should be implemented.

Retrofitting a building is required to ensure retained buildings contribute to reducing the UK's carbon emissions. Domestic energy use in buildings accounts for 69% of the operational emissions that come from buildings in the UK, which alone is responsible for 18% of the annual emissions *(LETI)*. Whilst reducing carbon emissions is the main driver, best practive retrofit should also reduce energy bills and also improve health and wellbeing.

The London Energy Transformation Initiative (LETI) published a Climate Emergency Retrofit Guide in November 2021, which provides an approach to retrofitting existing housing types to enable the Net Zero Carbon goals to be achieved.

The following hierarchical approach is advocated:

1. Reduce space heating demand and Energy Use Intensity
2. Remove fossil fuel heat sources and replace with low carbon alternatives
3. Generate renewable energy on site wherever feasible

An approach to historic buildings is discussed in more detail later in this chapter, although retrofit as a whole is a topic discussed in other publications.

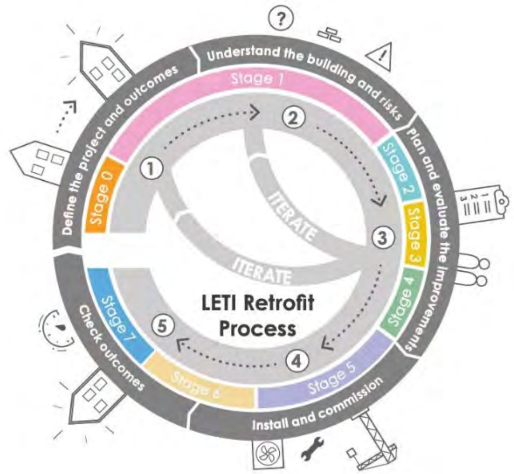


Image 14:

13 LETI Retrofit Process

Further Information

- [LETI Climate Emergency Retrofit Guide (2021)]

Definitions

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

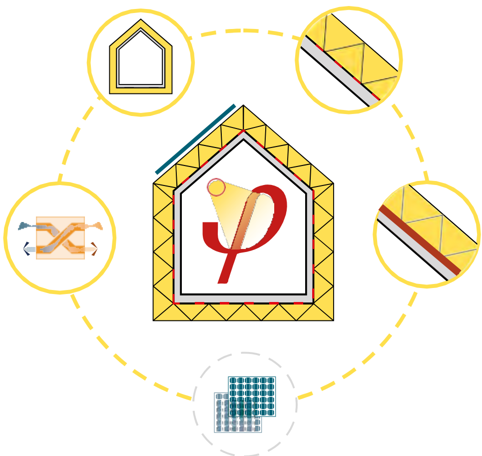
Passive Design

Minimising energy use through design needs to be factored in from the beginning of the design process. Implementing the **energy hierarchy** is an approach in support of this and one that should be applied to all development.

Buildings designed in line with the energy hierarchy prioritise lower cost passive design measures and take a fabric-first approach over high cost systems or and over-reliance on renewable energy technologies. In the long term this makes developments more cost-effective and allows investment costs to be recovered through operational savings.

An energy-led design approach starts with reducing the need for energy through passive design measures. Those include using form, orientation and fabric to maximise natural resources such as sun, ground, wind, and vegetation - and minimise the need for heating/cooling.

Proven standards like Passivhaus focus on minimising energy consumption, and provide a tested and measured route to achieving this. “”Passivhaus Plus provides a route to achieving Net Zero/Zero Carbon development by using additional renewable energy generation but with the emphasis remaining on step 1 of the hierarchy to minimise energy consumption..



Form and Orientation	1
Continuous Super Insulation	1
Draught-free Construction	1
Efficient Services (including MVHR unit)	2
On-site Renewables (Optional for Passivhaus Classic, required for Passivhaus Plus)	3

14 **Image 15**: Passivhaus Principles

Definitions

- **The Energy Hierarchy:**
  1. Reduce the need for energy through passive design measures including form, orientation and fabric;
  2. Install energy efficient mechanical and electrical systems, including heat pumps, heat recovery ventilation, LED lights, fittings and appliances;
  3. Maximise renewable energy through decentralised sources, including on-site generation, community-led initiatives and low and zero carbon technologies

Further Information

- Passivhaus Standards & Criteria

Site context - ie topography, existing built and natural environment: When looking at the building from an energy perspective, awareness of the surrounding area, and the impacts of over shadowing from vegetation, topography and surrounding buildings must be considered. A site design should aim to maximise the potential for solar gain (both for the building design itself, but also for the potential installation of solar panels), whilst also using land form and landscaping to provide shading to minimise heat losses in winter and provide shading in summer.

An awareness of sun paths and local climate provides energy benefits as well as a wider community benefit, creating character and pleasant bright spaces beside buildings. Evaluation of buildings once completed indicates spaces that are orientated sub-optimally so are heavily shaded most of the year and consequently underutilised. This does not lend itself to place making and creating community led social spaces.

Building form, orientation + layout: The internal and external design should work together to respond efficiently to overshadowing, internal heat gains, prevailing winds, light quality and spatial orientation with the building designed to minimise heating, lighting and cooling demand.

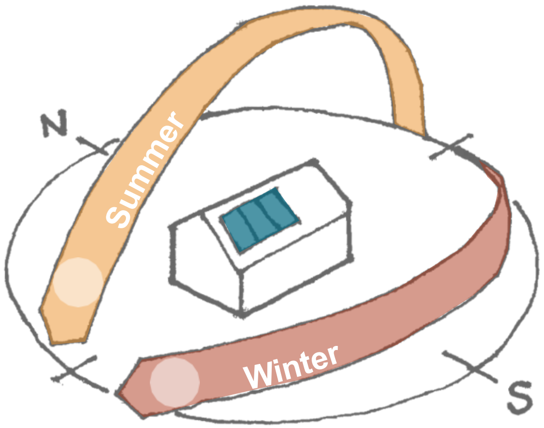


Image 17:
17 Sun Path Diagram

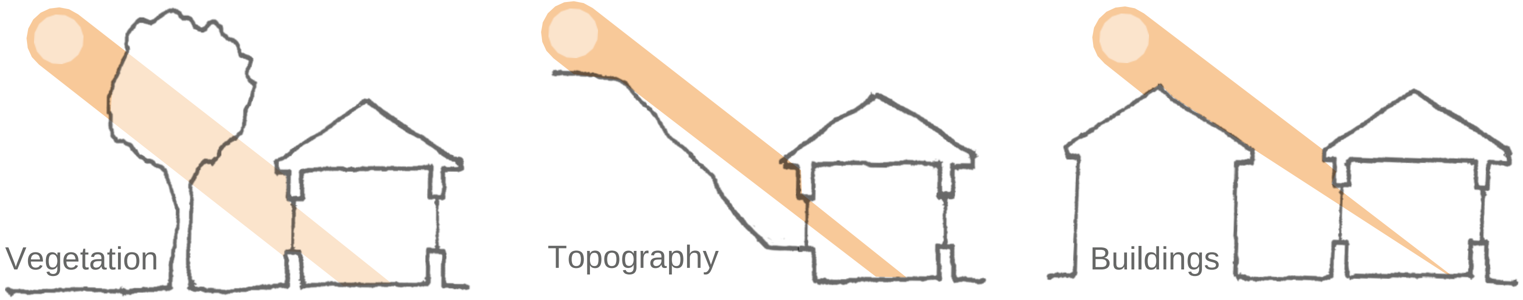


Image 16:
16 Site Context: Impacts of Overshadowing

An optimised orientation will have the main building facades and windows facing south and north (although north facing windows will lose more heat than they gain so should be assessed accordingly). Sometimes providing true north and south elevations is not possible due to site constraints and in this instance the '10 Degree Rule' can be applied. Solar gain drops off as the distance from true south increases but this isn't drastic until quite significant angles are achieved. For example, at around 20° off axis the building will still benefit from 90% of the available solar radiation. This maximises the amount of solar gains available to the building whilst maintaining consistent temperatures and daylighting inside through appropriate shading strategies. This does not exclude a building from having east and west facing windows however these present a higher risk of overheating and glare due to the lower angle of the sun.

Having a building oriented facing South to optimise solar gain means:

- Less onerous **building fabric** performance
  - › Reduced Fabric **U-value** permissible
  - › Less insulation (thickness) required
- More manageable internal comfort
  - › Optimises beneficial solar gains
  - › Lower overheating risk
  - › Simpler to shade/ manage glare

Having a building orientated East to West means:

- More onerous fabric performance
  - › More stringent Fabric U-value required
  - › More insulation required
- Less manageable internal comfort
  - › Undesirable solar gains
  - › Greater overheating risk
  - › Harder to shade/ manage glare

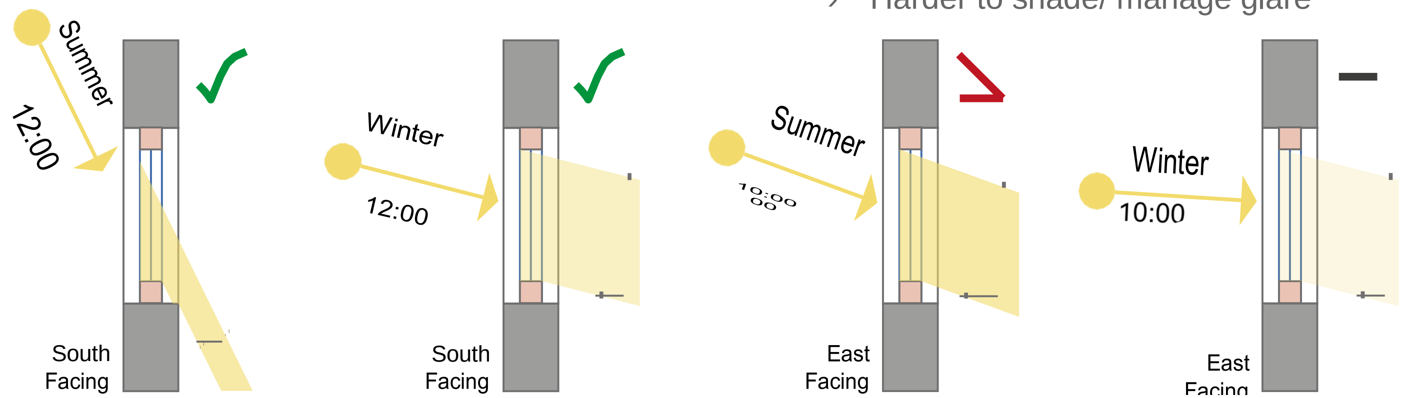


Image 18:
Orientation: Impacts on Solar Gains

Definitions

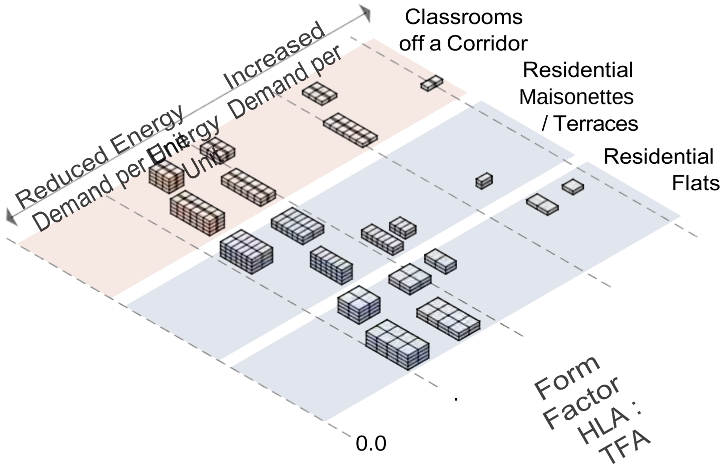
- **Building Fabric/ envelope:** consists of the external walls, roofs, floors, windows and doors and is the part of a building that protects the occupants from the external environment. It also controls the flow of energy and heat loss from inside to out.
- **U-value:** (measured in Wm2/K) – how readily energy (heat) will flow through a structure from inside to outside. It is a measure of the amount of energy (W) lost through a square metre (m2) of that material for every degree (K) difference in temperature between the inside and the outside.

A relationship between space requirements within the building and orientation should be incorporated from first principles. Positioning spaces so that those that require most warmth and daylight receive most passive solar gain and those spaces that need less warmth and daylight receive the least can ensure artificial lighting requirements are reduced as well as assisting the energy balance of the building. For example, in residential developments living and bedroom spaces are best located to the north and south, and bathrooms and circulation to the east and west. In a school it is best to have good daylighting in classroom spaces so these should be positioned with elevations to the north and south. In comparison, a workshop or plant room needs less daylight so could be positioned on the north or east elevations which also minimises the glazing requirement on these elevations and therefore less glare and overheating risk.

Optimising the massing of a building can create character and enhance wider social community involvement but must also be efficient in its design and placement. Creating an efficient form will often generate a higher density building rather than a low and spread-out building. However, there are many more factors such as orientation, daylighting, site constraints etc. that are important to consider when designing and the building form should be designed in conjunction with these. A compact building form does not guarantee an efficient building.

A buildings **form factor** is calculated by dividing the heat loss area (all external walls, roofs and floors) by the **Treated Floor Area (TFA)**, so relates to how much heat is needed to heat a space and how much heat is lost through the fabric.

A low form factor can reduce the heating demand and mean that the building specification can be relaxed whilst still achieving the same performance. Improving the form factor simplifies the building and can therefore result in cost savings by reducing the amount of building fabric and complex corner junctions. The form factor is only concerned with thermal elements. Architectural expression can still be achieved outside this envelope to give external space and elevation articulation.



19 **Image 19**: Form Factor

Definitions

- **Treated Floor Area (TFA):** A measure of internal space, within the thermal envelope of a building. Areas that have lower head heights or are not classed as liveable areas are counted but a reduced percentage applied.
- **Form Factor:** a tool often used to assess a design at an early stage and provides an early indication of the efficiency of the building shape, the lower the number the better.

Daylight & windows: As the internal layout of a building is developed, consideration must be given to the depths of rooms and spaces, to ensure the room can be evenly well-lit throughout the day without a reliance on lighting and to promote internal comfort and well-being.

Outlook is important but it is also critical to minimise unnecessary glazing that will create a risk of the building overheating or losing excessive amounts of heat (as windows will perform worse than external walls).

Glazing ratios, specification and configuration have a significant impact on the energy performance of a building.

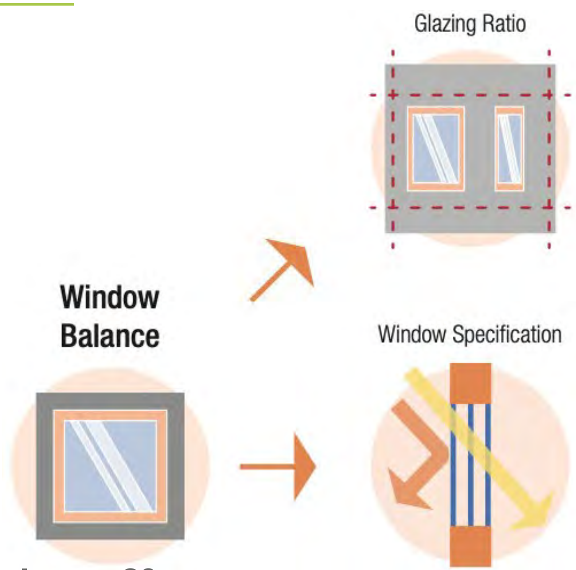


Image 20:
Glazing Ratio and Specification Balance

Generally, south facing glazing with a **brise soleil** for solar shading is favourable as it affords good solar gains in winter months when the sun is low in the sky and minimal gains due to the solar shading when the sun is high during the summer. East and west facing glazing afford reasonable winter solar gains and high instant summer gains which are not ideal.

An exemplar elevation design achieves a balance between optimising free solar gains, window heat losses, daylighting and overheating risk, whilst working aesthetically.

These ratios are not always achievable due to brief constraints as well as daylighting, access to views or for acoustic reasons. It is, however, where the ratio deviates from the ideal that a different aspect of design will have to compensate for performance losses, such as improved building fabric U-values.

A balance can be found within the specification to compensate for additional glazing but this has a significant capital cost impact as well as potentially increased maintenance and replacement costs. The latter is especially true if the glass required is of high performance specification to compensate.

- **Brise Soleil:** A solar shading system that use horizontal or vertical blades fixed externally to a building.

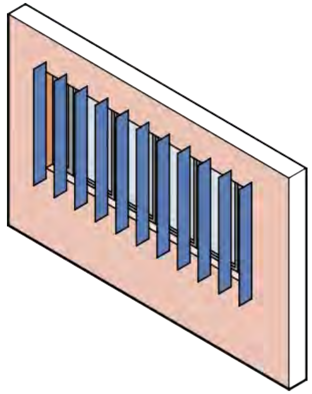
The sill heights and distribution of glazed area across the elevation (lots of little windows, versus a few large ones) are important factors in optimising the useful solar gains. Typically, windows down to floor level bring in higher levels of non-useful solar gain due to glazing below 800mm, or the 'working plane' in daylight modelling terms, by creating additional heat losses in winter, and additional heat gains/overheating in summer. This leads to thermal discomfort and requires complex services solutions to resolve.

Optimal glazing ratios have to be considered in conjunction with both designed and contextual shading as an overall approach and at each level of the building.

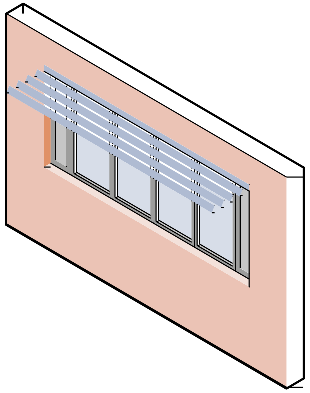
Shading: Shading is often required for buildings to control solar gains and glare. The shading of a building can be provided by the surrounding context, for example trees, topography and buildings as well as being designed as part of the building envelope.

Considered window and glazingdesign can help to reduce the need for it, but with the climate changing it is important to design an opportunity for further shading to be incorporated at a later date.

As explained in earlier sections it is easier to control solar gains to a building on the north and south elevations. External shading is advised over internal shading mechanisms as the heat has at that point already entered the building. Often internal shadingmechanisms can also be more costly. The use of shading systems such as **brise soleil** or vertical fins can be beneficial in reducing glare as well as overhanging eaves, deep window reveals and covered canopies and walkways. A general rule of thumb is that horizontal shading is more effective onsouth facing elevation and vertical shading on east and west elevations.



E/W-facing window



S-facing window

21 **Image 21**: Optimised shading orientations

Planting & Soft Landscaping: Vegetation, trees, and elements such as green roofs also have a role to play, improving outlook, managing air quality, stabilising microsystems and providing natural shading. Buildings should be designed to allow the benefits of planting to improve the internal conditions however they should not be reliant on them to do so; quite often the building's life expectancy exceeds that of the landscaping around it.

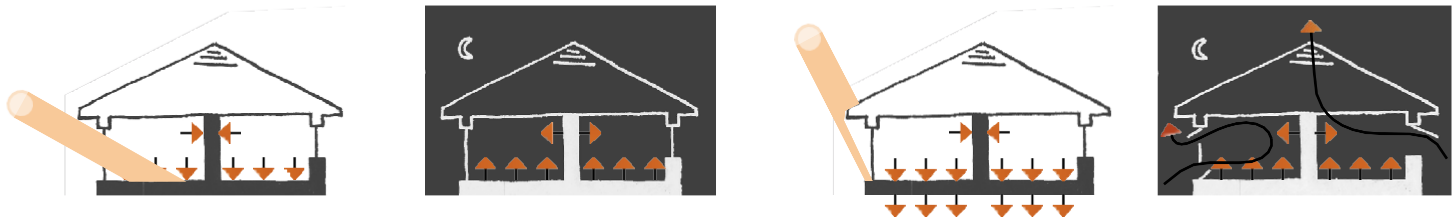
Thermal mass: Materials have the capacity to absorb and store heat and release this when temperatures are cooler. Some materials such as concrete and stone have a high thermal mass, whilst materials such as timber, a low thermal mass. The thermal mass of a building can be used to moderate the internal temperature of buildings, by storing the heat during the day and releasing it during the cooler night temperatures.

Generally, the more mass there is within the external thermal envelope the easier it is to control the possibility of overheating in summer months. A building with high thermal mass, exposed internally, will tend to have even temperatures and a good internal environment over the changing seasons, naturally reducing the risk of overheating. However, this does not require a building to be built in masonry. Solid ground floors and exposed plaster can both contribute to the thermal mass of the building.

Whilst thermal mass can be a benefit the impact is difficult to quantify and there is often a lag in response which needs to be considered along with the heating system design. Ensuring there is the ability to open windows securely, particularly at night time, is important in providing an opportunity to resolve this. Ultimately the design and benefit of thermal mass will depend on the context and will need to be considered in relation to the building.

In a Passivhaus building for example, large fluctuations in temperature are reduced through minimal heat loss, controlled ventilation and attention to avoiding overheating, so the benefits of thermal mass are reduced.

22 **Image 22**: Thermal Mass



Day (winter) - heat absorbed | Night (winter) - heat emitted | Day (summer) - heat emitted | Night (summer) - heat emitted

Fabric First Approach

A fabric first approach takes a design back to basics and is an approach to ensure the building itself reduces its energy consumption. An energy efficient building should achieve high thermal and airtight performance whilst also providing structural stability and weather protection. There are a few key principles that need to be addressed to achieve this:

Insulation: Firstly, it is important to minimise heat loss through the external fabric (which includes walls, floor, roof, windows and doors) by wrapping the building in a continuous layer of insulation. Each material has a calculated **lambda** value or ‘λ value’ which is then added to the other elements of the fabric in that section of construction (for example the wall) to provide a **U-Value.**

The thermal performance of a building structure is reviewed using U-Values. The lower the U-Value the better the thermal performance, as less heat is being transferred through this element. Building Regulations have set minimum requirements for the U-Values of each element but it is recommended that buildings should achieve the highest possible standards of thermal insulation, not minimum requirements.

Thermal bridging: Continuity of insulation is essential. The need for structural integrity, and the need to allow light and access into a building leads inevitably to the use of different materials with different thermal properties. Good design of each of these details to minimise the thermal loss is crucial both to keep heating demand down and to avoid cold spots or thermal bridging where condensation and mould might form. The effect that thermal bridging can have on the overall thermal performance of a dwelling can be significant.

Definitions

- **Lambda (λ) value:** (measured in W/(mK)) – measures the thermal conductivity of a material and is a value that indicates how well a material conducts heat. It indicates the quantity of heat (W), which is conducted through 1 m² wall, in a thickness of 1 m, when the difference in temperature between the opposite surfaces of this wall equals 1 K (or 1 ºC). The lower the λ value, the better the insulation property of the material.
- **U-value:** (measured in Wm2/K) – how readily energy (heat) will flow through a structure from inside to outside. It is a measure of the amount of energy (W) lost through a square metre (m2) of that material for every degree (K) difference in temperature between the inside and the outside.
- **Thermal bridging:** A thermal bridge, also called a cold bridge, is an area of a building construction which has a significantly higher heat transfer than the surrounding materials. This is typically where there is either a break in the insulation, less insulation or the insulation is penetrated by an element with a higher thermal conductivity.

Recent research undertaken has shown that thermal bridging can be responsible for up to 30% of a dwelling's heat loss *(BRE).*

Airtightness: Ensuring a building is airtight also contributes to eliminating draughts and cold spots, safeguarding internal comfort and energy efficiency. It has been identified that current building regulations must dramatically improve the airtightness requirements of buildings if we are to achieve the Government energy targets.

An air test to establish a building's airtightness should be completed on all new and renovated buildings. When carrying out an airtightness test, a steady-state condition is established, when the air blown out of the building by the fan is balanced by the air re-entering the building through various cracks, gaps and openings. Typically, this is at a pressure of 50 Pascals (Pa).

Current Building Regulations requirements are for a building to achieve an airtightness of <10m^3/h.m^2 @50pa. The National Future Homes Standard which comes into force in 2025 (although there will be an intermediate uplift ahead of this date) and replaces the Building Regulations Part L 1A standard for conservation of fuel and power in new dwellings, will require a change to <5m^3/h.m2 @50pa. This is the equivalent to a hole the size of a 20p piece in each square metre of external fabric. In contrast building to achieve the Passivhaus standard requires an airtightness of <1m^3/h.m^2 @50pa for refurbishment (to the Passivhaus enerpHit standard) and <0.6m^3/h.m2 @50pa for new build. To put this in perspective this is a hole the size of a 5p piece every 5 square metres of external fabric.

An end airtest will often be required upon completion for certification but it is advisable that earlier tests are completed as a check and to allow rectification if needed. Good design requires decision on an air barrier strategy, deciding what products and processes are required to deliver an agreed target airtightness. On larger developments assigning an airtightness champion will help achieve an airtight design and the quality assurance needed. Failing an airtest can often be costly requiring additional works and delay.

Windows: Window design is important in a fabric first approach, forming a significant part of the buildings envelope. Careful consideration needs to be given to creating the right size and proportion of windows and the right orientation so that the resultant solar gain reduces the need for heating, as discussed earlier. Triple glazed windows shouldb e installed which effectively act as radiators in the winter. These combined with the high levels of insulation also mean that other every day activities such as people and appliances also contribute to heat generation in winter, resulting in a home that requires very little heating.

Definitions

- **Airtightness:** the ‘leakiness’ or ‘draughtiness’ of a building. It is a factor in the energy performance of a building; less airtight buildings can waste energy by losing warm internal air to the atmosphere and taking in cold air from the outside during the heating season.

The detailing around windows and openings are often potential areas for cold bridges and airtightness issues. A window forms part of the insulation and airtightness layer and so the window must be positioned in alignment with the insulation (ideally centrally) and detailed (often with tapes and membranes) to ensure it is not a weak point in the airtightness layer.

Consideration regarding glazing configurations was discussed earlier in relation to solar gain and shading. The configuration is also important from a fabric first approach. When designing a highly insulated building triple glazing provides the best energy balance and is needed to meet comfort requirements and to avoid condensation and mould at the edges. The U-Value of a window the manufacturer provides is for the whole component, frame and glazing. Each of these also has a U-Value which when assessed in relation to amount of frame and glazing a whole window U-value can be calculated.

Generally, frames perform worse than triple glazing so small windows, or those with lots of mullions and transoms should be minimised - could one larger window provide the desired daylight into a space rather than 2 smaller? Equally where possible consider glazed doors as these generally perform better than solid doors. Tilt and slide doors and inherently more airtight than parallel slide versions, whilst bi-fold doors are generally more expensive if they achieve a good level of airtightness. Note that rooflights are very difficult to shade from overheating in summer.

Although outward opening windows are more common in the UK market, when planning to use a high performance energy efficient window it is worth noting that a high proportion open inwards. Inward opening windows allow external shutters, blinds or insect mesh to be fitted, and are usually easier to wrap in insulation, thus helping achieve better thermal performance. This will need to be factored in to the design particularly if there is the cill were to be a feature, such as a window seat.

Image 23:
23 Architype, image by Richard Kiely

Best Practice Recommendations

- A fabric first and building physics approach to be implemented during all design stages.
- Achieve an air permeability of below $3m^3/h.m^2$ @50pa in all new developments. However an airtightness of <$0.6m^3/h.m^2$ @50pa required for Passivhaus is encouraged. For an airtightness of below $3m^3/h.m^2$ @50pa this will need to be in combination with a mechanical ventilation heat recovery system.

Overheating

When applying the earlier guidance to improve the fabric performance and maximise solar gain it is essential that these are considered alongside measures to address overheating. Energy efficiency measures and external temperatures as a result of urbanisation and climate change are increasing the risk of overheating in existing buildings especially in those that primarily rely on passive measures to achieve year-round internal comfort.

Image 24:
24 HARC, Architype ©DennisGilbert/VIEW

High internal temperatures are detrimental to internal comfort and productivity and excessive or prolonged high temperatures have significant impacts on the safety, health and well-being of the ooccupants. Summer temperatures are set to rise by half a degree in the UK by 2050, with urban areas set to experience higher temperatures and so overheating must be addressed.

In the past air conditioning has been a solution to higher temperatures, particularly in non residential buildings in the UK but the focus on reducing energy consumption and carbon emissions now mean these are not economically or environmentally viable.

Methods to manage solar gains, such as window design, shading, the surrounding context and orientation have been discussed in earlier sections to minimise energy consumption. These measures also help to control overheating, with the ratio of glazing on building elevations critical to achieving this. The Good Homes Alliance has published a helpful tool to identify overheating risks in new homes such as ensuring single aspect buildings should also be avoided as these are more prone to overheating due to lack of cross ventilation and solar gains occurring at the same time, thereby increasing the peak solar gains.

Best Practice Recommendations

- All new development to be designed and built to meet CIBSE TM59 overheating standards. Future climate scenario modelling to also be completed. The Good Homes Alliance overheating tool could be used for smaller developments.

Further Information

- The Good Homes Alliance Overheating in New Homes

Managing solar gain is one element to managing the overheating risk alongside a robust ventilation strategy. Natural ventilation should be provided where suitable, with cross ventilation encouraged.

However passive design principles should not be relied upon as the only method to combat the risk of overheating and natural ventilation should be evaluated in relation to site constraints to its effectiveness in mitigating overheating. Additional to this a whole building mechanical ventilation heat recovery system is recommended, ensuring a consistent amount of fresh air into each room of a building.

Analysis of the building is important at the early design stages to establish if overheating is a risk.

Thermal modelling software, that for example is used when designing a Passivhaus building can analyse the buildings performance and if internal comfort will be affected throughout the year. The Chartered Institution of Building Services Engineers (CIBSE) has published criteria for assessing overheating along with future climate scenarios which should be used when completing overheating assessments.

Post occupancy evaluation and in-use monitoring are recommended to assess the buildings real life performance against performance that was anticipated at design stage (**the performance gap**) to establish if the building performs as expected and if not allows rectification measures to be put in place.

Definitions

- **Post Occupancy Evaluation (POE):** the process of obtaining feedback on a building's performance in use.
- **Performance Gap:** the difference in how a building was anticipated to perform at design stage and the in-use energy consumption.

Further Information

- Overheating, CIBSE
- CIBSE TM52 The Limits of Thermal Comfort: Avoiding Overheating in European Buildings (2013)
- CIBSE TM59 : Design Methodology for the Assessment of Overheating Risk in Homes (2017)
- Overheating in new homes: Tool and guidance for identifying and mitigating early stage overheating risks in new homes, Good Homes Alliance (2019)

Ventilation

In the past buildings have relied on the opening windows and air permeability through the building fabric for ventilation. Designing energy efficient buildings which are highly insulated and with minimal air permeability requires a considered approach to ventilation to minimise build-up of moisture, CO^2 and other internal pollutants.

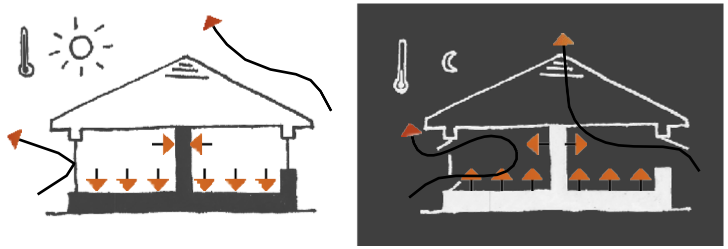
Studies show that the average Indoor Air Quality (IAQ) in modern homes with natural ventilation via trickle vents is poor. As the majority of the day is spent in-doors, a long-term exposure to polluted and oxygen-depleted air is likely to have negative health implications. A building that is well ventilated, will provide a healthy and comfortable environment for the occupants along with minimising the risk of overheating.

Natural Ventilation & night time cooling: Where local environmental conditions permit (e.g. noise, air quality), openable windows should be included as they allow building users the opportunity for natural ventilation. Cross ventilation is encouraged, and single aspect buildings should be avoided.

Buildings should be designed, where possible to allow for windows, panels or louvres to provide ventilation at night as it is important that heat built up during the day is allowed to escape at night (night time cooling). The location, size and controls of these must be designed to ensure adequate ventilation can be achieved simply and securely. Concerns over security at night and complicated controls can result in these systems being underutilised or disabled.

Building Regulations require mechanical ventilation to be installed in spaces where heat and moisture is created, for example bathrooms, kitchens and utility rooms. The regulations require a level of extraction depending on room function, with the warm moist, stale air extracted to outside. Consequently, heat loss from the building is significant.

Passive Ventilation with Heat Recovery (PVHR): Systems such as Passive Ventilation with Heat Recovery rely on natural ventilation but recover heat from the stale exhaust air, helping to reduce heat loss from the building. These wall and roof mounted systems can also provide secure night time cooling.



Day - heat absorbed Night - heat emitted

25 **Image 25** Night Cooling

Mechanical Ventilation with Heat Recovery (MVHR): As natural ventilation relies on wind speeds and temperatures, which an airtight building will not have, only natural ventilation in a building with a good level of airtightness should be avoided. In these buildings, a mechanical ventilation heat recovery (MVHR) system should be installed to retain the heat and provide a constant supply of fresh oxygen filled air (that is also filtered for pollutants and pollen). These systems cut out most of the ventilation heat losses which make up to 30% of the heating demand of a dwelling *(PAUL, MVHR)*.

MVHR is a mechanical ventilation system that uses very little energy, extracting warm stale air from kitchens and bathrooms and transfering about 90% of that heat into the fresh air entering the building. This warmed fresh air is then supplied to all other rooms in the building.

The summer bypass mode allows the MVHR unit to circumvent the heat recovery mode during warmer months. This ensures ventilation is provided continuously without warm and humid air entering unnecessarily which can assist in reducing summertime overheating.

The inclusion of an MVHR system should be considered at the very beginning of the design process as there must be space for the unit itself and ducting as well as the requirement to set a good level of airtightness to be achieved. An air permeability of no more than 3m³/h.m2 @50pa should be set for the inclusion of an MVHR system.

The primary maintenance requirement for an MVHR system is low tech and requires changing the filters. Some ventilation units maintain a constant air flow rate when filters get clogged, but in so doing the fans get noisier. So regular filter changes are important and should be factored into a maintenance regime/contract.

The main advantages of an MVHR system are:

- I mproved energy efficiency of the building due to a substantial reduction in heat loss .
- Reduction in Noise – an MVHR system is a ventilation solution that does not require windows to be opened, particularly if a building suffers from external noise e.g traffic.
- Air quality improvement – If the air quality of a building is problematic, for example external pollutants, smells, pollen etc the MVHR filtration system can reduce/eliminate the impact of these.
- Reduced humidity – an MVHR system will dehumidify the building when outside is colder than inside.
- Higher comfort levels – a constant supply of fresh air, that is draught free.

Best Practice Recommendations

- Installation of Mechanical Ventilation Heat Recovery (MVHR) in all buildings where possible.

Image 26:
26 Passivhaus Logo

The Passivhaus Standard:

The Passivhaus Standard is an integrated design methodology. It began as a piece of research into how to deal with the **performance gap**; the difference between how simulated buildings perform, and real buildings perform. The research found that comfort and construction quality were the two key areas leading to the performance gap. This research led to the creation of a comfort standard that has a very low energy demand with minimal performance gap, known as the Passivhaus Standard. Many years later, thousands of projects have been completed and certified with an abundance of **post occupancy evaluation** data proving that the standard delivers.
At its core, the Passivhaus Standard is a comfort, quality and energy standard. The comfort and quality criteria are what deliver the low energy performance that Passivhaus has become famous for. Integrated thinking is key to achieving the Passivhaus Standard. The Passivhaus Planning Package (PHPP) should be used as a tool to optimise design as well as to demonstrate compliance.

There is a hierarchy of building design aspects needing to be addressed, and how these affect building performance. In order of significance they are: form and orientation, façade, fabric and **MEP**/ services specification.

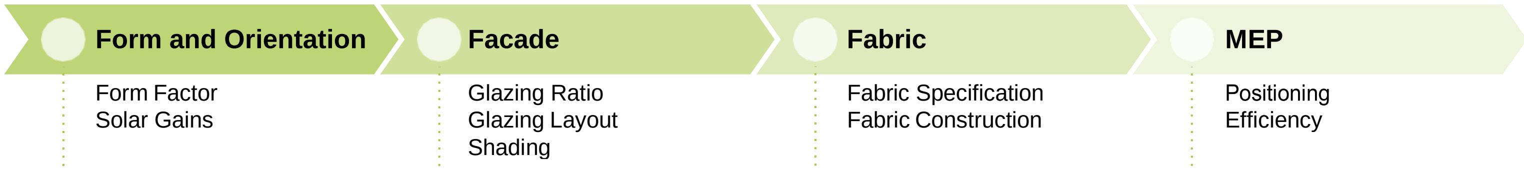


Image 27:
27 The Passivhaus Hierarchy

Definitions

- **Performance Gap:** the difference in how a building was anticipated to perform at design stage and the in-use energy consumption.
- **Post Occupancy Evaluation (POE):** the process of obtaining feedback on a building's performance in use.
- **MEP:** stands for Mechanical, Electrical and Plumbing systems.

Best Practice Recommendations

- All new building to achieve the Passivhaus Plus Standard, incorporating renewable energy within the design, thus leading to a Zero Carbon future.

Key features of Passivhaus:

Super insulation
Stringent levels of airtightness
Minimal thermal bridging.
Optimisation of passive solar gain
Mechanical ventilation with heat recovery
Triple glazed windows

As the Classic standard does not specify where the energy comes from, it is the Passivhaus Plus and Premium standards that can allow a Zero Carbon development to be achieved through the use of renewable energy. For difficult cases, where building for a variety of reasons, may not meet the Passivhaus criteria, the Passivhaus Low Energy Building Standard may be suitable.

The EnerPHit standard: For low energy retrofit projects, the standard is slightly relaxed to take into account the existing building and potential conservation constraints that mean the Passivhaus standard is not feasible.

Passivhaus comfort criteria focuses on thermal, air, and acoustic quality.

- **Thermal comfort** / Passivhaus buildings have stable, even temperatures throughout. This is a result of criteria for temperature, ventilation and airtightness criteria that minimise draughts.
- **Air Quality** / Passivhaus buildings deliver constant high levels of fresh air to where it is needed, which improves air quality substantially compared to other buildings.
- **Acoustic Quality** / Passivhaus buildings typically require triple glazing which, along with the high levels of insulation and reduced requirement for opening windows for ventilation, helps to significantly reduce external noise pollution.

Passivhaus is a route to minimising the energy consumption of a building. It is important that the design is approached holistically, considering also embodied carbon, water use, ecology and waste management. When all of these areas are addressed can the development be truly sustainable.

Heating Demand	Or	Heating Load	Airtightness	Or Frequency of Overheating
15 kWh/m²a		10 W/m²	0.6 ACH	10% ideally <2%
Cooling Demand	**Or**	**Cooling Load**	**Primary Energy**	**Or Primary Energy Renewable**
15 kWh/m²a		10 W/m²	135 kWh/m²a	60 kWh/m²a

Image 28: 28 Key Passivhaus Classic Requirements

All figures relate to **Treated Floor Area (TFA)**

Definitions

- **Treated Floor Area (TFA):** A measure of internal space, within the thermal envelope of a building. Areas that have lower head heights or are not classed as liveable areas are counted but a reduced percentage applied.

Why Passivhaus?

- Excellent comfort levels and improved indoor air quality
- Consistent fresh air throughout the building
- Very low energy and running costs, which is important as energy prices continue to rise
- Durable, robust and well detailed construction

Healthy Internal Environments

Material Choice: Building biology considers the relationship between occupants and the spaces designed for living and working. It is about the creation of healthy, beautiful and sustainable buildings through the selection of materials and t he design of the internal environments. Much of that discussed earlier in this chapter and in later chapters contributes to the creation of this healthy environment.

The interior design and selection of internal finishes and materials is an important element to creating this and the following should be considered in material selection:

- Low or non toxic materials without VOC's (Volatile Organic Compounds)and formaldehyde contents - Choose low VOC or water based paints, avoid using caulk which has high levels of VOC's and choose solid timbers over products made to look like wood.
- Water-based finishes – choose paints, varnishes that are water based rather than chemically based.
- Natural materials and fibres -The more natural the product the better it will be for air quality inside the home. Choose for material finish to be its natural finish such as lime plaster walls, stone floors rather than applying a chemical sealant as this will reduce its benefits. Alternatively there are a number of natural sealant options available.
- Responsibly sourced wood products and timber – Choose FSC certified timber, which ensures it grown in well-managed forests preferably in the UK.
- Locally sourced materials, products and crafts – Support local businesses and reduce a products carbon footprint.

RIBA 2030 Climate Challenge target metrics for all buildings

Best Practice Health Metrics		References
Overheading	25-28 °C maximum for 1% of occupied hours	CIBSE TM52, CIBSE TM59
Daylighting	> 2% av. daylight factor, 0.4 uniformity	CIBSE LG10
CO_2 levels	< 900 ppm	CIBSE TM40
Total VOCs	< 0.3 mg/m³)	Approved Document F
Formaldehyde	< 0.1 mg/m³)	BREEAM

Image 29:
29 RIBA 2030 targets

Further Information

- Building Biology

Embodied Carbon

Embodied carbon refers to the emissions produced by the products, construction, in-use maintenance and end of life processes associated with the b uilding. The embodied emissions can range from 30-70% of the life cycle emissions of a building. As buildings become more energy efficient and electricity decarbonises, embodied carbon will represent a higher proportion of the whole life carbon than it currently does.

The embodied emissions are broken down into life cycle stages A, B and C. In essence, stage A emissions have been emitted by the completion of the building, stage B emissions are emitted throughout the life of the building, and stage C emissions are emitted at the building's end of life.

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

30 **Image 30**: Building Lifecycle Stages

Throughout the life cycle of a building, the certainty of its carbon emissions decreases, particularly given that a building's life cycle is typically assumed to be 60 years. Emissions from Stage A are very predictable. Stage B is dependent on when maintenance is required, and how much manufacturing improves emission rates over time. Stage C is dependent on when the building is demolished, and what improvements are made to waste management streams by that point. To minimise variables, life cycle analysis considers what would happen in all stages under current day circumstances. It would therefore be fair to consider that emissions further into the future are less significant than those now.

31 **Image 31**: CO^2 contributions of a building

Some definitions often referred to when discussing embodied carbon include:

Sequestration: refers to the process by which organic materials sequester carbon during growth e.g. a tree absorbing carbon then being cut down and used as construction timber would typically sequester an amount of carbon.

The concept of quantifying carbon sinks within landscape has a wider potential and appeal to link also to ecology and biodiversity agendas. All parts of the soft and hard planning of a site provide an opportunity for carbon capture/sink devices and give a more holistic integrated view of carbon within a development.

Carbonation: refers to the process by which some materials absorb carbon through their life cycle e.g. exposed concrete continues to absorb carbon for years after curing.

The London Energy Transformation Initiative (LETI) have published useful guidance regarding Embodied Carbon, including where the largest proportion of embodied carbon can be found within each building typology and also within each building element, along with targets to take us to 2050.

Building Performance Embodied Carbon

Design and material choices throughout the development will have associated carbon impacts and so decisions can be taken to reduce the embodied carbon of a building.

Reduce	i. consider retention and adaptation of existing buildings ii. reuse existing materials on site where possible iii. simplify the design iv. provide efficient space design, creating flexible, multifunctional spaces v. review the use of materials and if they could be used more efficiently and sparingly vi. Reduce transportation by choosing locally sourced materials.
Context	Design to work with the existing site topography, minimising the need for excavation and removal of land from site
Efficiency	i. Minimise waste by designing to standard material sizes or repetition (which also minimises waste on site) ii. Consider the structure and lightweight construction methods to minimise foundation and transportation requirements iii. Consider openings sizings and open plan spaces and minimise the need for large structural elements iv. Design for multifunctionality, such as the structure also providing shading requirements v. Design well and eliminate the need for materials, such as exposing services.
Longevity	Consider the life span of products and ensure longevity.
Low-carbon	Minimise materials with high embodied carbon content, choosing materials that have a recycled content (such as GGBS instead of cement and low carbon concrete mixes)where possible
Natural	Choose natural, responsibly sourced materials and renewable materials and avoid treatments as often these can limit recyclability options
Adaptability	i. Design for flexibility and adaptability to allow the building to be repurposed in the future if needed ii. Design for ease of demolition (mechanical fixings as opposed to adhesive) at the end of the buildings life and to allow for materials to be re-used or recycled

The London Energy Transformation Initiative (LETI) is a network of over 1000 built environment professionals that are working together to put London on the path to a zero carbon future. However, these targets are not specific to London and can be applied to buildings across the whole of the UK. LETI have produced a number of informative publications including one-pager guides that are in alignment with other initiatives including the RIBA 2030 Climate Challenge, with the ultimate aim to achieve the Government target of net zero carbon for the whole UK building stock by 2050.

LETI, along with others such as RIBA 2030 believe that in order to meet our climate change targets all new buildings must operate at net zero carbon by 2030 and all buildings must operate at net zero carbon by 2050.

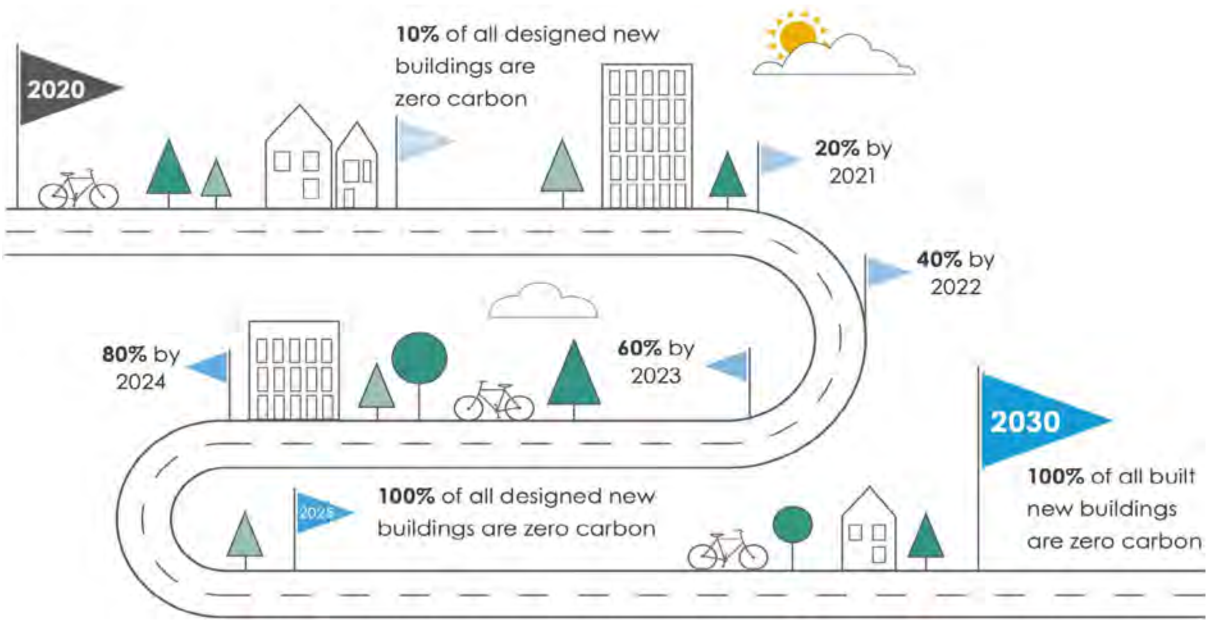
LETI identifies a number of elements to achieving net zero carbon by 2050, including operational energy and embodied carbon, with targets set to ensure this is achieved. Importance is also given on data disclosure, to provide opportunity to learn from the existing building stock and eliminate the 'performance gap'.

LONDON
ENERGY
TRANSFORMATION
INITIATIVE

32 **Image 32**:
LETI Logo

Further Information

- LETI Climate Emergency Design Guide: How new buildings can meet UK climate change targets
- LETI Climate Emergency Retrofit Guide (2021)



33 **Image 33**:
LETI Getting to Zero

Building Performance Embodied Carbon 3.9

Embodied emissions benchmarks are an evolving area for the construction industry. The RIBA 2030 Climate Challenge forms sensible reference benchmarks for different building typologies (see below).

There are several tools for measuring embodied carbon, but embodied carbon should be analysed using the RICS Whole Life Carbon Assessment for the Built Environment professional statement 2017 methodology and approach and include modules A1-5, B1-5, C1-4 (including sequestration), including a minimum of 95% of the cost allocated to each building element category (0-7 of Table 3, page 11 of RICS Whole Life Carbon Assessment).

On projects where Whole Life Carbon assessments are not being undertaken as part of the project team's core services, effort should be focussed on reducing embodied carbon following the hierarchy in LETI design guidance, and reasonable endeavours should be made to quantify the embodied carbon savings achieved. Analysis tools such as ECCOLAB may be used assist the process.

Best Practice Recommendations (for New Developments)

- Target an embodied carbon performance of <750 $kgCO^2e/m^2$ for non-domestic office buildings and <625 $kgCO^2e/m^2$ for domestic buildings, <540 $kgCO^2e/m^2$ for education buildings and <535 $kgCO^2e/m^2$ for retail by 2030 (minimum 40% reduction in embodied carbon compared to the current business as usual benchmarks) by using low carbon materials that are responsibly and ethically sourced.
- Evaluate embodied carbon using the RICS Whole Life Carbon Assessment for the Built Environment professional statement 2017 methodology.
- On projects where Whole Life Carbon assessments are not being undertaken, effort should be made to reduce embodied carbon and quantify the embodied carbon savings achieved.

Further Information

- LETI Embodied Carbon one-pager
- RIBA 2030 Climate Challenge
- ECCOLAB, web based decision support tool for design of low impact buildings
- RIBA Embodied and Whole Life Carbon Assessment for Architects (2017)

	Office ($kgCO^2e/m^2$ [GIA])	Residential ($kgCO^2e/m^2$ [GIA])	Education ($kgCO^2e/m^2$ [GIA])
Business as usual	<1400	<1200	<1000
2025 RIBA Target	<970	<800	<675
2030 RIBA Target	<750	<625	<540

34 **Image 34**:
The RIBA 2030 Climate Challenge embodied carbon targets

Householder Extensions

Regardless of scale all development has an important role in reducing the impact the built environment is having on the Earth's natural resources. By applying many of the measures discussed in this document to the design, will ensure an energy efficient extension which minimises its impact on the environment but will also save the homeowner money and improve the internal comfort of the space. Although some measures may increase the cost of the build, the saving over time or payback period must be factored in as the cost of energy is likely to continue to rise.

36 **Image 36**: dempseydecourcyarchitects.co.uk/passivhauslowene.html

Best Practice Recommendations (for Householder Extensions)

- Consider and implement the nine householder environmental building considerations.
- Consider extending the environmental improvements to the existing property, and look to achieve the Passivhaus EnerPHit standard as a whole house approach.

Could the existing space within the property be repurposed, avoiding the need for the extension? Will the extension make some parts of the existing property redundant?	Can demolition be avoided and if not can materials be salvaged and reused?	Develop a passive design approach- consider the orientation and form, insulation and detail design, windows and shading
Develop the surrounding context as well as the extension – consider the inclusion of vegetation, soft landscaping and water management features to improve the setting	Review the ventilation approach and potentially adding mechanical ventilation, whilst also ensuring there is adequate natural ventilation	Consider the materials used in the build and choose those which will reduce your carbon footprint
Installation of efficient services, fixtures and fittings	Installation of renewable energy (such as solar hot water or solar panels)	Water recycling

35 **Image 35**: The nine householder environmental building considerations

Historic Buildings and Buildings within a Historic Setting

To meet the Governments climate targets we need to reduce the energy consumption in all buildings, not just new developments. Maintaining existing buildings is an important climate action as even after refurbishment the embodied carbon is significantly less than the new build option.

Climate change can impact the historic environment, for example erosion of archaeological sites through severe weather and flooding, harm to historic landscapes and weathering of the building fabric. Similarly energy efficiency measures if not appropriately considered can have a negative impact on the historic environment, for example causing damage to fabric by changing the conditions in which it was designed to exist.

When considering the historic context a balance must be found that allows the character and appearance to be preserved and enhanced but that also limits the impact further damaging emissions and allows adaption to climate change. Choosing high quality and fit for purpose materials and appropriate design measures is fundamental.

Where a historic or listed building forms part of a wider development whole estate goals can be considered.

Adaption to energy requirements and climate changes can and must happen to avoid the deterioration and redundancy of heritage assets, avoiding prioritising an asset for ourselves over future generations. Conservation by definition is the managed preservation of a resource to avoid destruction.

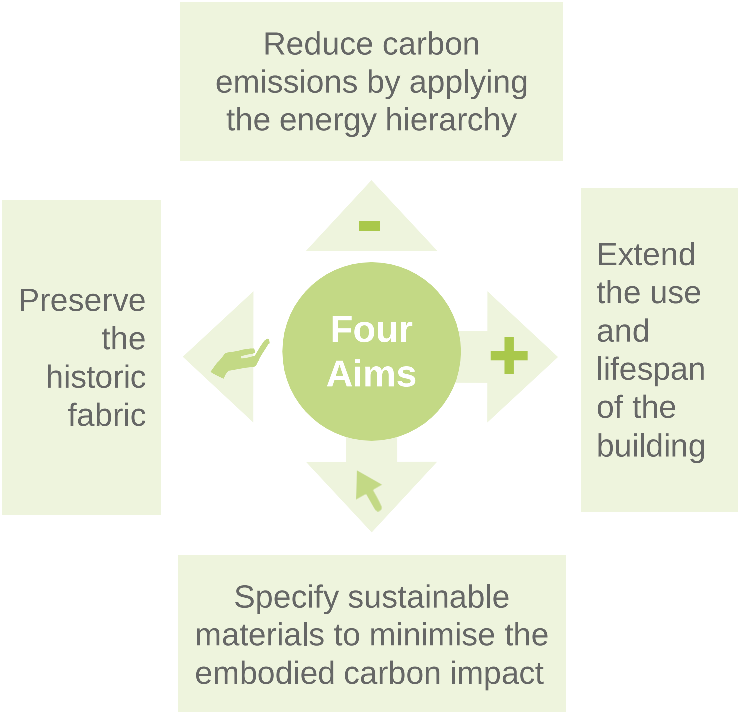
Historic buildings have fundamental differences in how they have been designed to manage heat and moisture, and the skills and materials needed to maintain, repair, and responsibly adapt them. Consequently, some solutions developed for modern day construction may not be appropriate and could be damaging to the building and potentially causing harm to the health of the occupants.

When improving the energy importance of a historic building it is important to consider a wholeh ouse approach/strategy. It may not be possible to complete all works at the same time and so the impact a phased approach will have on the buildings performance must be considered. The four aims when improving the sustainability of heritage assets are illustrated opposite.

Ultimately the most effective way for a historic building to be as energy efficient as possible is to keep it in good repair, avoiding the requirement for energy to rectify a problem.

Ensuring a building can regulate the moisture levels within it and its structure is also important as moisture effects thermal performance and creates unwelcome internal environments.

Before undertaking any works to a listed building or building in a conservation area seek advice and approval from the conservation team in Herefordshire Council.



37 **Image 37**: Four Aims for Improving Heritage Assets

Best Practice Recommendations (for historic buildings)

- Consider all 4 Aims when working with a historic building.

Further Information

- Climate Change, Sustainability and Energy Efficiency, Historic England
- Energy Efficiency and Historic Buildings (2018)
- Energy Efficiency and Traditional Homes (2020)
- Planning responsible retrofit of traditional buildings, Sustainable Traditional Buildings Alliance (STBA)(2015)

Best Practice Recommendations

PF1 Prioritise the refurbishment and retrofit of existing buildings where possible. Also, aim to re-use elements of existing buildings if at all possible, for example foundations (subject to structural engineer input), bricks or even floorboards for a new purpose.

PF2 A fabric first and building physics approach to be implemented during all design stages.

PF3 All new building to achieve the Passivhaus Plus Standard, incorporating renewable energy within the design.

PF4 Achieve an air permeability of below $3m^3/h.m^2$ @50pa in all new developments. However an airtightness of $<0.6m^3/h.m^2$ @50pa required for Passivhaus is encouraged. For an airtightness of below $3m^3/h.m^2$ @50pa, this will need to be in combination with a mechanical ventilation heat recovery system.

PF5 All new development to be designed and built to meet CIBSE TM59 overheating standards. Future climate scenario modelling to also be completed. The Good Homes Alliance overheating tool could be used for smaller developments.

PF6 Installation of MVHR in all buildings where possible.

PF7 Target an embodied carbon performance of $<750\ kgCO^2e/m^2$ for non-domestic office buildings and $<625\ kgCO^2e/m^2$ for domestic buildings, $<540\ kgCO^2e/m^2$ for education buildings and $<535\ kgCO^2e/m^2$ for retail by 2030 (minimum 40% reduction in embodied carbon compared to the current business as usual benchmarks) by using low carbon materials that are responsibly and ethically sourced.

PF8 Evaluate embodied carbon using the RICS Whole Life Carbon Assessment for the Built Environment professional statement 2017 methodology.

PF9 On projects where Whole Life Carbon assessments are not being undertaken, effort should be made to reduce embodied carbon and quantify the embodied carbon savings achieved.

PF10 Householder Extensions: consider and implement the 9 householder environmental building considerations.

PF11 Householder Extensions: consider extending the environmental improvements to the existing property, and look to achieve the Passivhaus EnerPHit standard as a whole house approach

PF12 Consider all 4 Aims when working with a historic building.