Putting Passivhaus into practice

Passivhaus - an introduction

Passivhaus is a voluntary standard of rigorous, energy-efficient design.

It is the gold standard to aspire to.

It brings clarity. It signifies to the team that this project isn't going to be business as usual, that there are clear principles and standards that everybody is working to; and that this is going to be a very low energy building.

The Standards

Passivhaus is the most scientifically ratified and internationally recognized energy efficiency standard for buildings.

There are various levels to the Passivhaus standards which become more advanced and stringent as they progress.

The Passivhaus standards

- **Passivhaus Classic**
- **EnerPHit**
- **Passivhaus Plus**
- **Passivhaus Premium**

All levels of the standards focus on the overall building performance with the latter two pushing harder and moving towards a 'power plant methodology' where the building starts to generate energy rather than simply consume it.

With a mid-rise development the more advanced standards really start to put the building design under very specific stresses and strains.

Passivhaus Classic is most suitable for a new build scenario, with EnerPHit brought out shortly afterwards as a retrofit standard with some slight reductions in what needed to be achieved.

Busting some Passivhaus myths

'.... Its only for houses'

Passivhaus is used on residential schemes far beyond houses with the highest certified scheme currently standing at 88m. Beyond residential schemes Passivhaus is used extensively on commercial projects and mixed-use schemes.

When looking at mixed use it is possible to create multiple models for the single project and submit separately, or to identify which element will be Passivhaus and which not.

'.... It limits design and restricts creativity'

The Passivhaus name still conjures up the stark germanic box for many, but as the Passivhaus Standards are more readily accepted to the mainstream, the more precedents there are which confirm that it need not constrain innovation and creativity.

The key is to consider Passivhaus as an iterative process from the outset so that it helps guide design decisions rather than dictate them.

'.... It makes buildings warm, dry, and stuffy'

Ventilation is the number one that everything should hinge around in a Passivhaus scheme. Make strategic decisions and design the ventilation strategy and solutions to suit the building use.

Understanding the terminology

The various terminology used when referring to environmental impacts is confusing at best. If one person's **carbon negative** is another's **carbon positive,** then is it better to be **carbon neutral** or **zero carbon?**

Why carbon? Carbon emissions are the biggest, most obvious, and tangible measure of our negative environmental impact. Ways to reduce carbon emissions are central to most of the targets set for reducing environmental impacts.

Carbon or energy? Carbon emissions and energy use are intrinsically linked, with energy use a given in our daily lives and a key contributor to carbon emissions. The two terms are used interchangeably because of this.

Embodied energy / carbon is that within the fabric of our built environment, that with which it is created. This can be in the manufacture and/or extraction of building materials and in the construction process.

Operational energy / carbon is that used to run our buildings; to heat, light and cool them. Taken as a lifetime measure.

Key targets

Carbon Neutral (also Zero Carbon) refer to a zero balance being achieved between the carbon created during a building's construction and in operation, and that offset by the new environment.

Carbon Negative (also Carbon Positive) refers to actively removing carbon emissions from the environment by offsetting more carbon production by the new environment than was created during construction and in operation.

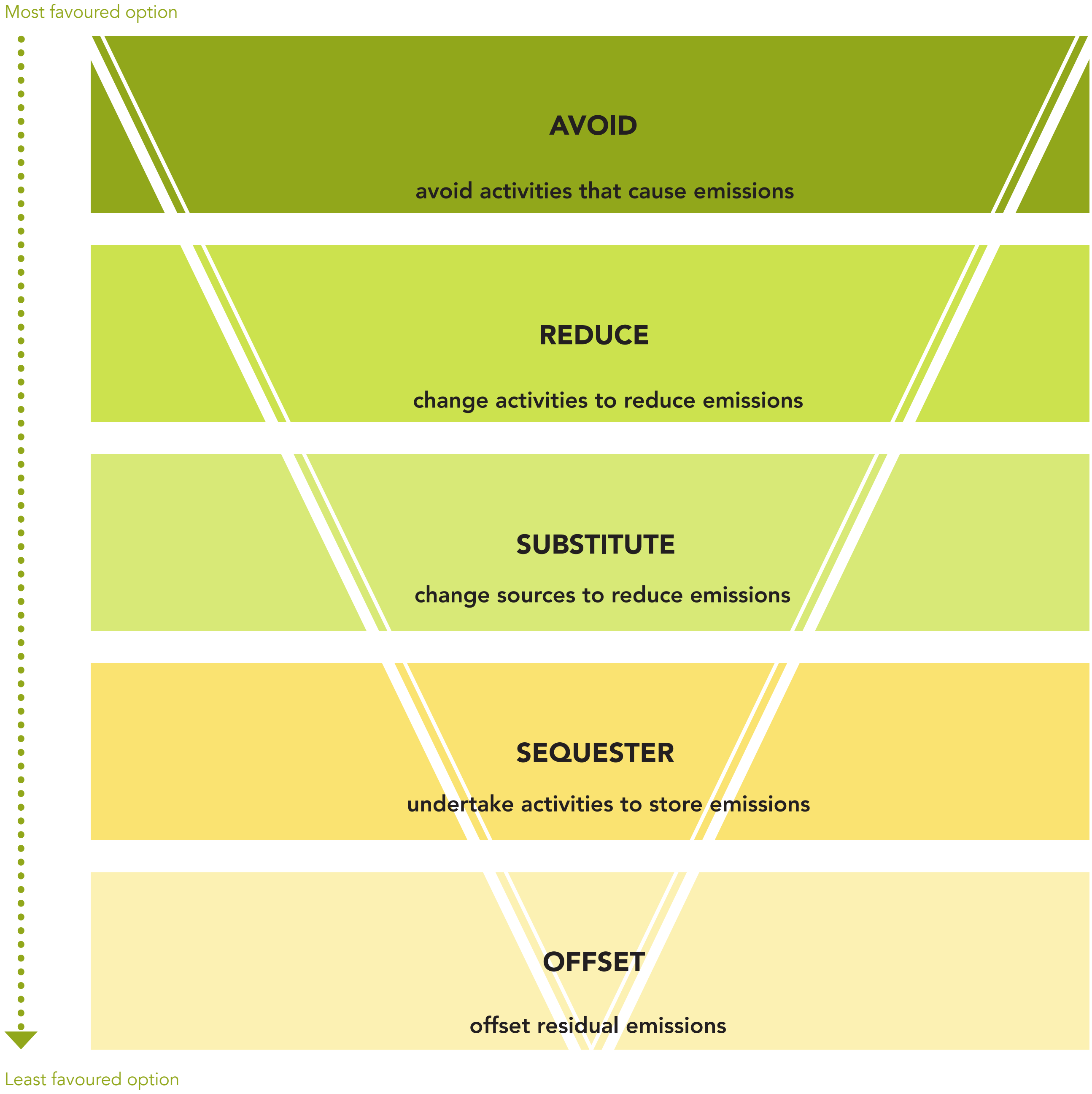
Whilst they have a common goal, the strategies adopted to achieve zero carbon versus carbon negative status has a big impact on their long-term efficacy against climate change.

The aims of both are to:

- Reduce embodied carbon.
- Reduce operational carbon - design for performance, creating a stable environmental that requires less operational energy to maintain heat and light levels.
- Create a positive balance. If additional operational energy is required then:
  - Adopt renewable energy sources locally,
  - or remotely,
  - Sequester carbon through soft landscaping (for example)
  - Finally offset.

The latter is the most contentious as if offsetting is used as a key principle, it does not tackle the performance of what we are designing and building.

Carbon management hierarchy



Passivhaus in medium rise residential developments

Challenges of meeting Passivhaus in medium rise residential projects

Passivhaus Standards are largely concerned with operational energy use.

In a medium rise residential development it is often easy to meet the space heating demand and airtightness criteria due to the superior form factor (a ratio of the internal floor area to the total building envelope area).

However, as such developments contain many relatively small individual dwellings each with their own cooking, lighting, hot water requirements etc the total energy consumption per m² can be more of a challenge.

Whole building demand

When we consider zero carbon goals for operational energy, we review the whole building demand including heating, domestic hot water, electricity use, and ventilation.

In a medium rise development, the Passivhaus approach to building design can vastly reduce the operational energy use associated with heating and domestic hot water usage. To maintain air quality the energy use associated with ventilation remains similar if not a little higher.

The operational electricity use of the building is dictated by its users not the building design, considering activities like putting on the kettle, hairdryer, TV etc. This is often referred to as unregulated energy and is not considered in SAP calculations. However, as part of the overall operational energy demand of the building it should be considered as part of the move towards zero carbon.

The domestic electricity is the one variable in the whole building demand that Passivhaus design standards and principles cannot reduce.

The approach with the whole building demand is to review the areas where positive impact can be felt and use these to counteract those we cannot impact upon.

Power generation

The other thing to consider is that whilst we cannot impact upon the electricity demand within the home, we can consider opportunities for the building to generate power to offset that which its occupiers use.

Solar PV panels are an incredibly cost-effective solution for urban energy generation.

Experience has shown us however that on the medium rise development the available roof space in comparison to the number of dwellings limits the number of PV panels we can accommodate, and this in turn impacts the amount of energy demand that can be met for the building.

In the example used we have an 8-storey building with 78 apartments. The calculations allowed for a maximum 374 PV panels that would only meet 37&% of the building energy use.

So whilst PV is an incredibly cost-effective solution for urban energy generation, the higher the standards, and more stringent the requirements, their use must be quite innovative and areas beyond the roof must be considered.

Key considerations – a strategic approach

To achieve the standards, consider them from the outset of the design process. Changes to a design on the drawing board are far easier than changes to the design during construction.

A larger medium rise scheme will benefit from a Passivhaus Designer. They will work alongside the Architect to model the building and consider its holistic performance. The earlier the designer is engaged, the more embedded the approach will become to the design, and the more effective the early design decisions become.

A medium rise development will also need to engage a Passivhaus Certifier who ratifies the project against the International Passivhaus Institute's requirements. They will undertake reviews of the project at key stages:

- Initial check
- Preliminary review
- Design review
- Post Construction review

The design review is critical, as all involved will know at this point that the scheme will be accredited or not. The final post construction review, including air pressure test of the building, will give final determination that the scheme has passed the standard and the certificate will be issued.

Design Principles - Form

Building form: Form Factor

The form factor is the ratio for heat loss between the exposed building envelope and gross internal floor area.

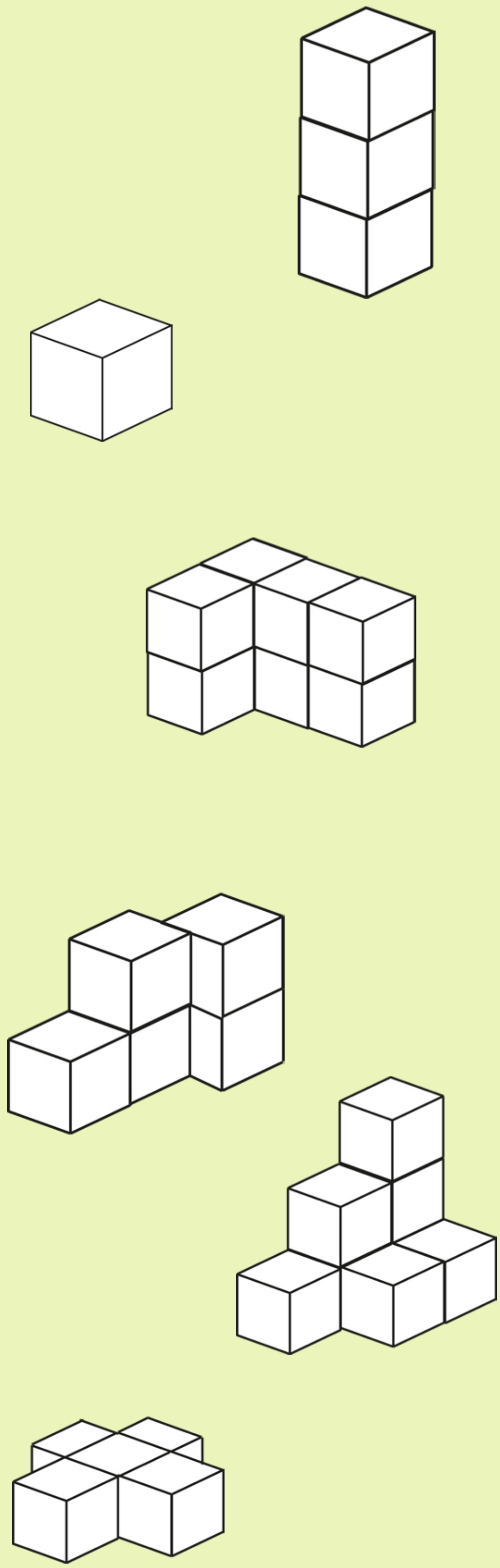
There is a metric often used in Passivhaus design – the form heat loss factor. This is the ratio for the heat loss across the building.

The form factor is calculated by dividing the sum of the heat loss area (walls, floor, roof, windows, etc.) by the treated internal floor area.

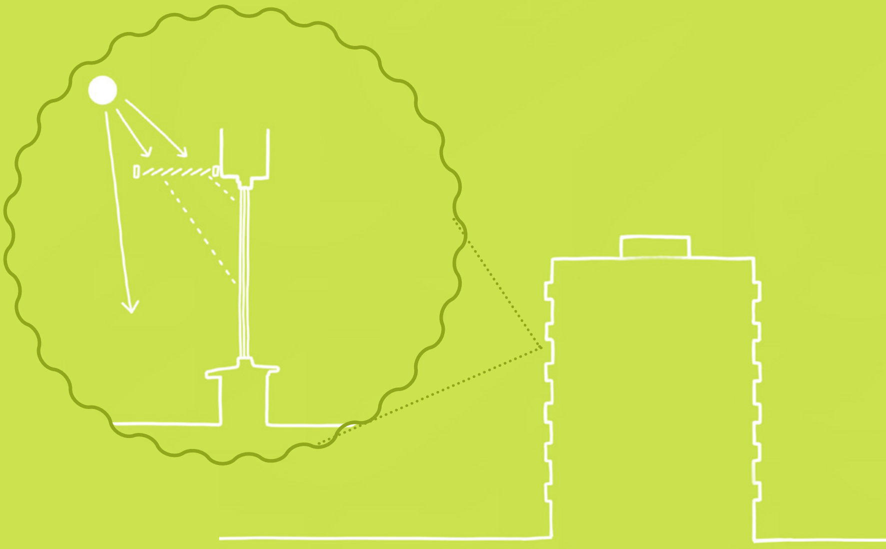
The higher the form heat loss factor the less thermally efficient the building form.

A cruciform bungalow for example will have one of the highest heat loss form factors at approximately 4.5 ranging to a very tall multi-storey block with a form factor of around 1 or less.

This then equates to the requirements for insulation that will be required to meet the Passivhaus standards, with the bungalow with form factor 4.5 requiring 450mm to the high-rise block with a form factor of 1 requiring only 100mm.



Beneficial solar gain



Orientation

Start with **fabric-first principles,** making the built form do the hard work for you before looking to design the services.

To maximise solar gain orientate the building with its largest surface area (usually its longest facade) facing south.

Dwellings are ideally dual aspect, with south-facing habitable rooms that utilise the solar gain to their benefit.

In reality, this is not always possible in an urban context as planning constraints and solar shading from adjacent buildings come into play. Also an apartment building is unlikely to have dual aspect rooms and so designers look to other tools in their kit to manage the solar gain and create balance between not enough and too much.

Glazing

Triple glazing is required to achieve Passivhaus standards. Their effectiveness against heat loss can reduce energy demand by up to 10kwh from 25 to 15.

Glazing-to-wall ratios are key. Wider, shorter windows improve daylight distribution and moderate overheating risk as they are typically easier to shade and increase the openable area for ventilation (they also provide increased privacy to bedrooms).

Horizontal Windows sized to balance heat loss and gain can however appear ungenerous and often do not relate to local context. **Architectural features** such as spandrel panels and textured brickwork can be introduced to achieve a balance of solid to 'apparent' void to mitigate this.

Shade

Creating shade. Start thinking about the shading as soon as you think about windows and window placements on façades. Ways to shade glazing include:

- Fixed external shading
- Deployable external shading
- Balconies
- Shading within the window unit

Glazing Dos and Donts

As a rule do:

- Size glazing for daylight
- Size for ventilation
- Size for views out

And don't:

- Include lots of east and west facing glazing.
- Include unshaded east, south and west facing glazing.
- Design glazing for aesthetics only.
- Design glazing to maximise passive solar gain.

Understanding the thermal line

The thermal line

The thermal line is a continuous insulation line that marks the separation of heated and unheated areas of a building.

A façade that can on first impression appear very simple and elegant, can be complex when considering the thermal line and heat loss.

Consider the **thermal line** and **thermal envelope** behind. Irregular placement of building elements such as inset balconies that stack and step backwards and forwards across a facade create a complex thermal line which is more difficult to detail and more likely to fail.

Try to **group unheated spaces**, and if possible position them outside of the thermal line for efficiency. If they are inside then grouping them together makes things easier in terms of detailing and where you take the installation line, and air tightness line. This can apply to areas like bin stores, substations, bicycle parking and so on.

Balconies and private amenity space

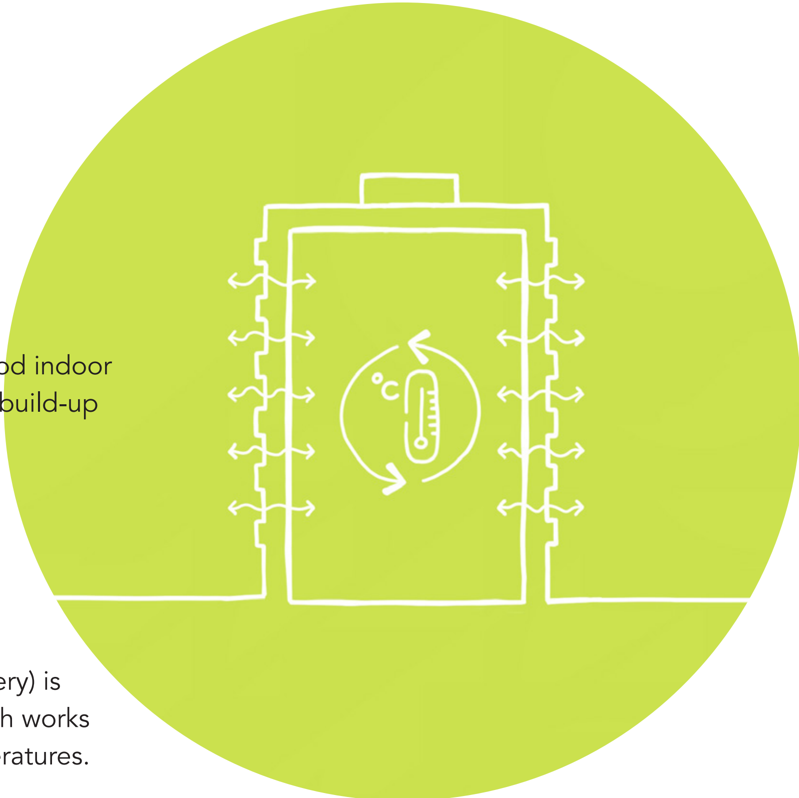
There are ways to create balconies and private amenity space that are thermally efficient and allow good daylighting, and ways that are more challenging:

- Irregular placement and offset patterns of balconies create complex issues.
- Inset balconies lengthen the thermal line, regularly stacked inset balconies are better than irregular placed ones.
- Balconies separate from the main structure, supported from the ground, or hung from above are the best performing.
- Consider the form of the balconies and their structure in relation to balance between shading and the available daylight to the interiors in both summer and winter.

An example was given of a balcony with brick pillar – the glazing to the rear of the balcony was receiving only 20% of daylight falling to the front face and glazing to the side receiving only 10%.

Design Principles - Ventilation

Ventilation



Effective ventilation is vital for ensuring good indoor air quality, with the ability to mitigate heat build-up and to remove excess moisture.

MVHR

MVHR (Mechanical Ventilation Heat Recovery) is an energy recovery ventilation system which works between two air sources at different temperatures.

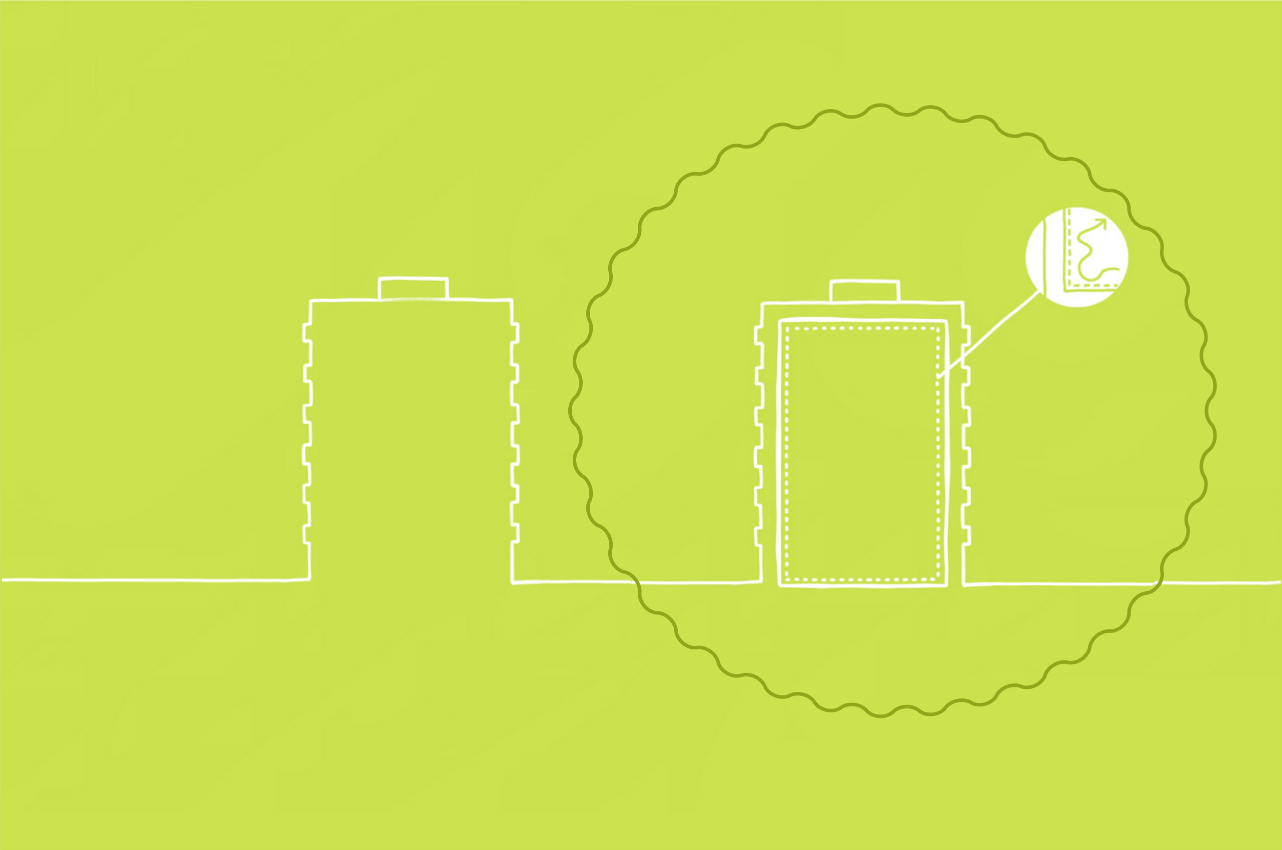
In dwellings MVHR units extract moist warm air from kitchens and bathrooms for example, exchanging the heat to incoming cold fresh air, and then supplying that air to the other rooms in the home.

When not required the heat recovery can be automatically bypassed to provide ventilation without noise or security issues.

MVHR in Apartment Schemes

Some points to understand when using MVHR in an apartment scheme

- A centralised ventilation system benefits from a single intake and extract. However, space needs to be allowed for multiple risers. Dampers will also be required to prevent the spread of fire inside the ductwork through fire-rated walls and floors.
- Decentralised systems avoid the need for dampers but provide Multiple penetrations through the thermal and airtightness line.
- To minimise cold bridging the MHVR should be located on an external wall keeping the length of the intake and exhaust ductwork under 2m.
- The MVHR needs to be carefully acoustically separated from habitable rooms.
- In a deck access scheme, the utility is ideally located on a North facing walkway side.
- In a single aspect dwelling, the utility location is not as ideal, but can be incorporated in the second bedroom with access from the living room.
- The filters need to be replaced regularly so need easy access.



Air tightness

Air tightness is one of the most important factors in delivering against the Passivhaus principles. It impacts both fabric protection and comfort, and in turn the energy demands over each year.

By example using the PHPP model to compare the annual heating demands of a Passivhaus standard scheme at 15kwh, and a scheme that retains the same principles but reduces the air tightness to building regs limits; the heating demand in the latter increased to more than double that of the Passivhaus standard design.

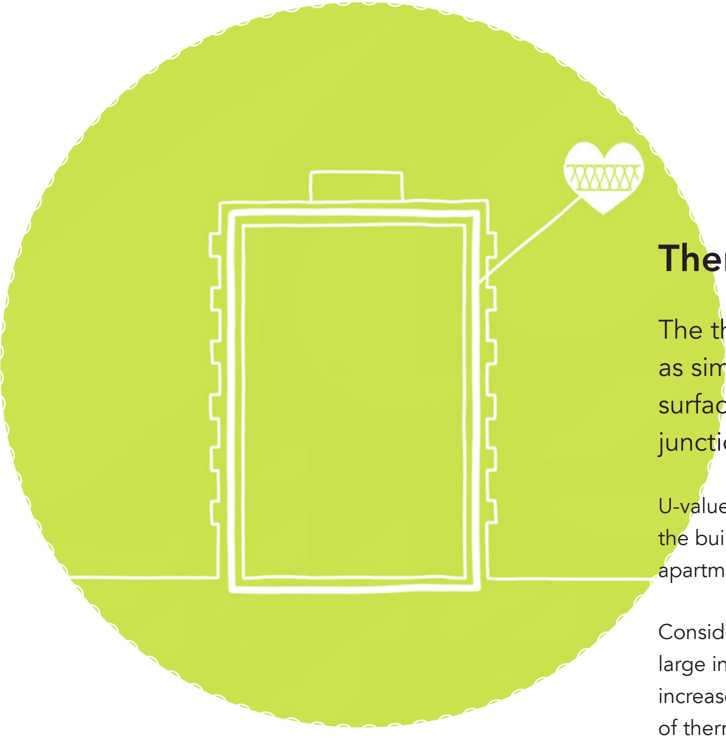
Six steps to achieve an airtight building

There is some good guidance on airtightness from the Passivhaus trust that identifies six steps that are fundamental to achieving an airtight building:

1. Keep designs simple.
2. Choose robust materials and don't substitute onsite.
3. Think about junctions in 3D, visualise how they will be built and produce clear drawings that illustrate this.
4. Communicate verbally, ensure all parties have understood the design, use site meetings, workshops, phone calls.
5. Put sensible site management processes in place, employ an airtightness coordinator and educate subcontractors.
6. Undertake leakage tests whilst the air barrier is still accessible.

The air tightness test is a useful proxy to the whole building quality inspection as any defects will show up in the test regardless of where they are.

Design Principles - Thermal Performance



Thermal performance

The thermal envelope of the building should be as simple as possible. This reduces the exposed surface area for heat loss and simplifies construction junctions.

U-values for apartments vary depending on the form factor of the building, but are generally a lot lower than in houses, as apartments have only one or two external walls.

Considering the building envelope very low U-values require large insulation filled cavities. Masonry supports and ties need to increase in gauge accordingly, which can in turn increase the risk of thermal bridging which we are aiming to avoid.

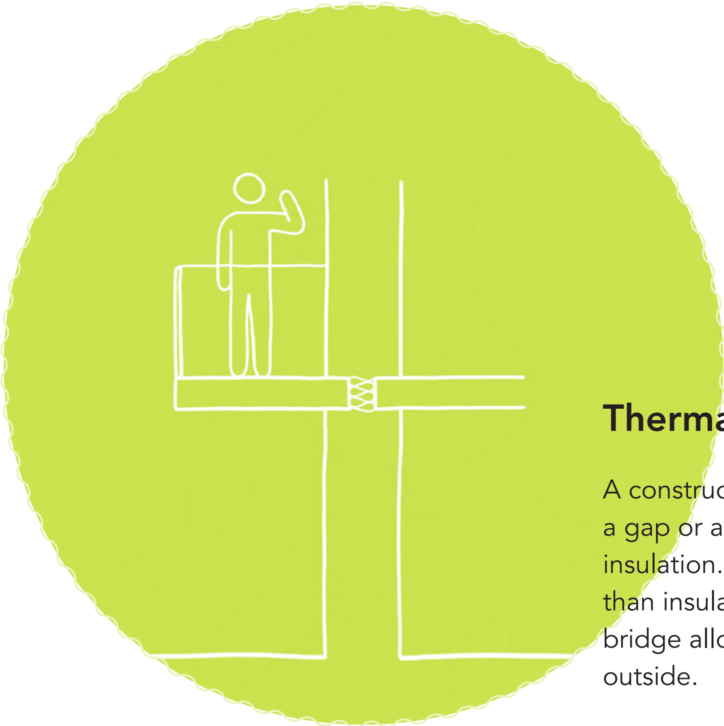
Our target u-values for the Passivhaus schemes are shown here, in comparison to the part L values:

Element	Targeted U-value Passivhaus	U-value Part L
Floor	0.184 w/m2K	0.25
Roof	0.181	0.2
Walls	0.180	0.3
Windows	0.8	2.0

It is very important to simplify the thermal envelope.

Avoid overhangs or undercrofts and Inset balconies, which increase the form factor, area of external wall and length of thermal bridges.

Penetrating the thermal envelope should also be avoided where possible. For example, air omittance valves are used so that soil and vent pipes vent at the head of the drainage run. Rainwater pipes are ideally located outside the thermal line, but if internal need to be insulated.



Thermal bridging

A construction thermal bridge is where there is a gap or a component that passes through the insulation. This component conducts heat better than insulation and therefore effectively forms a bridge allow heat transfer between inside and outside.

Thermal bridges should be avoided where possible. If we cannot avoid bridges, thermal breaks need to be introduced or low thermal conductivity components substituted. Examples include:

- Using low conductivity Basalt fibre Teplo-ties in the wall construction.
- Positioning windows in the insulation zone is a tactic to reduce thermal bridging.
- Deep brick reveals increase the risk of cold bridging and ties back to the inner structural leaf need to be carefully considered. Thermal breaks should be used between the window and masonry support.
- Introducing thermal breaks to reduced height parapets at the roof, essentially sitting the feature outside the thermal line.
- Simplify the ground floor line of insultation by introducing a thermal break above the pile cap.

The standards in detail

The standards outlined

Passivhaus Standard

- Primary energy demand ≤120kWh/m2 per year
- Space heating demand ≤15kWh/m2 per year

  (Around about a 90% reduction on a typical building which is normally between 175 and 230 kwh/m2/year)

- Space cooling demand ≤15kWh/m2 per year
- Specific heating / cooling load ≤10 W/m2
- Frequency of overheating (>25°C) ≤ 10%
- Airtightness ≤0.6 air changes/hr @n50

  Air tightness is fundamental to the Passivhaus standards. The standard required is significantly (approximately ten times) better than the typical requirement for compliance. Every building must be tested to achieve the standard which is quite different to a sap-based approach.

- PER Demand ≤ 60kWh/m²a

  (±15kWh/m²a with compensation with on-site energy generation)

Passivhaus Plus

As standard plus:

- PER Demand ≤ 45kWh/m²a (±15kWh/m²a with compensation with on-site energy generation)
- Renewable energy generation ≥ 60kWh/m²a (with reference to building footprint)

Passivhaus Premium

As standard plus:

- PER Demand ≤ 30kWh/m²a (±15kWh/m²a with compensation with on-site energy generation)
- Renewable energy generation ≥ 120kWh/m²a (with reference to building footprint)

EnerPHit

As classic except:

- Space heating demand ≤ 25kWh/m²a (≤ 20kWh/m²a in London)
- Airtightness pressurisation test result (n50) ≤ 1.0 ach

The standards

BREEAM is the longest established and is widely recognised as the industry standard sustainability assessment methodology. It is a holistic assessment measuring against nine categories including: Energy, Waste, Water, Materials, Health and Wellbeing, Transport, Pollution, Land Use & Ecology, and Management.

It has a very broad remit and gives a full picture of the sustainability of a project.

Nabers UK has recently been launched by the BRE. Originally an Australian energy and operational performance assessment, Nabers looks at the operational performance of buildings.

It helps us get a clearer picture of the energy use of buildings and addresses the gap recently identified with energy in use calculation stated as on average 3.8 times that of the predicted Part L calculations.

WELL and Fitwel are both standards that focus on health and wellbeing. The wellness of the occupants is considered with for example credits for designing buildings that prioritise stair use over lifts, healthy food choices, and having ADs on each floor.

There is a very high focus on the air quality in buildings with both standards.

Passivhaus looks at a very specific area of the sustainability map and is largely concerned with operational energy use. With a focus on kilowatt hours rather than CO_2, Passivhaus has one of the largest impacts upon residential energy costs.

Core to the Passivhaus approach is reduction of the performance gap by continual and robust analysis, design and testing.

Buttress

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