Easi Guide
Passivhaus Design

Medium density housing projects

Endorsed by: Passivhaus Trust

Etude   Levitt Bernstein People.Design

What is Passivhaus?

Passivhaus is a standard for the design and construction of comfortable, highly energy efficient buildings with set performance targets. It is the gold standard and first step towards achieving a net zero operational carbon building.

At Levitt Bernstein and Etude, our priority is to design good housing of lasting quality for all. We view Passivhaus considerations as a design opportunity, rather than a constraint. The following pages set out simple guidance that forms the foundations of good Passivhaus design. This will need to be combined and balanced with best practice planning of high quality homes for specific contexts.

Environmental impacts at concept design

Decisions made during the early design stages often have a significant impact on energy consumption in buildings. Consumption can be significantly reduced by considering the ten points in this guide, alongside design motivations and other constraints.

What should the designer focus on?

A good Passivhaus design is based on:

- **Free heat in winter** from solar gains with predominant façades facing south and limited overshadowing
- **Simple building form** for the warm spaces with a low exposed surface area
- High levels of **insulation**
- An extremely **airtight** building fabric
- Significantly reduced **thermal bridges**
- High performance **triple glazed windows** with window proportions that are based on orientation
- Opening windows for **natural purge ventilation**, with the ability to cross ventilate
- Efficient **background mechanical ventilation with heat recovery** (MVHR)
- Accurately predicted energy use modelling using the Passive House Planning Package (**PHPP**).

Key benefits

For residents:
- Improved thermal comfort
- Good indoor air quality
- Low heating requirement and low energy bills.

For clients:
- Ensures quality of design and construction
- Sets heating and energy targets that must be met
- Reduces the risk of fuel poverty
- Building compatible with net zero carbon.

PHPP modelling

A Passive House Planning Package (PHPP) calculation needs to be undertaken by an experienced/qualified professional for each building. This modelling helps to predict energy use, inform the design and determine Passivhaus compliance. Modelling is carried out at the end of RIBA stages 2, 3, 4 and 5 to check the building is meeting the required criteria (below) as it develops.

Passivhaus criteria in the UK

Space heating demand	<15 kWh/m²a.yr
Space cooling demand	<15 kWh/m²a.yr
Primary energy demand (PER) including all energy uses	<60 kWh/m²a.yr
Airtightness (*approx. air permeability of <0.6 m³/h.m²*)	<0.6 ACH

Myth busting

Myth 1: Passivhaus is just for dwellings
Passivhaus design can be used for a variety of building typologies, such as schools, offices, care homes and hotels.

Myth 2: You cannot open the windows
Windows can be opened to allow natural purge ventilation when needed. The difference is there is background MVHR, so heat will be kept in, the air will be filtered and the system will keep humidity low, even when the windows are closed.

Myth 3: Passivhaus costs 25% more
Although there will be an uplift in the building fabric costs, these are partially offset by the reduction in building services. Passivhaus certified homes cost approximately 3-8% more (construction cost) than a Building Regulations compliant building (refer to Passivhaus Trust's Construction Costs report from October 2019).

Myth 4: Adding more insulation will cause overheating
As well as keeping heat in during the colder months, insulation and airtightness will also keep heat out during the summertime. The overheating risk should be designed out by choosing appropriate glazing ratios, considering window orientation, openings and shading from the outset.

Form and orientation

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. However, the thermal envelope is often 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.

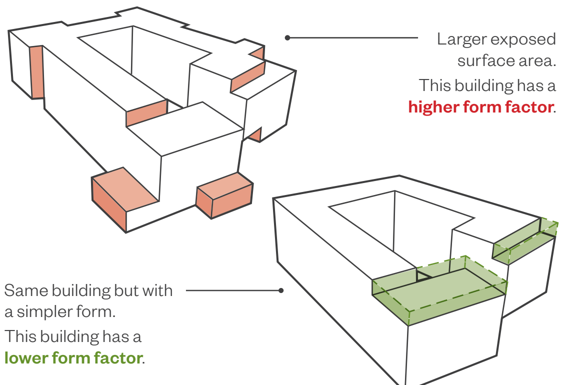
1 Compact building massing

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.

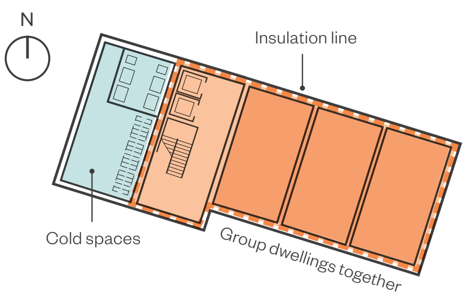
The lower the form factor the more energy efficient the building is. A form factor of below two is typically expected for a mid-rise apartment building.

Join homes into terraces and simplify the form of apartment buildings where possible.

Be strategic about adding articulation to the building form. Emphasise a few key design features that really matter in the context. The fewer stepped roofs, roof terraces, overhangs and inset balconies, the lower the heat loss from the building.



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



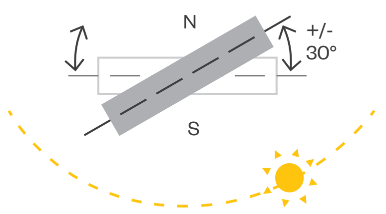
2 Space for unheated facilities

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.

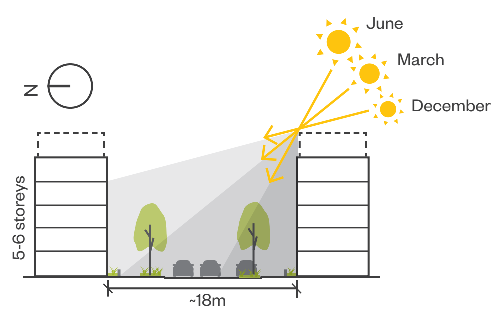
When these spaces are neighbouring a warm part of the building, such as a dwelling, the party wall and separating floor above need to be highly insulated.

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

3 Heat from the sun in winter



Prioritise dual aspect, south-facing dwellings. 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, this reduces the heat gain from the sun in winter. Allow 1-1.5m of distance for every 1m of height.

Window design

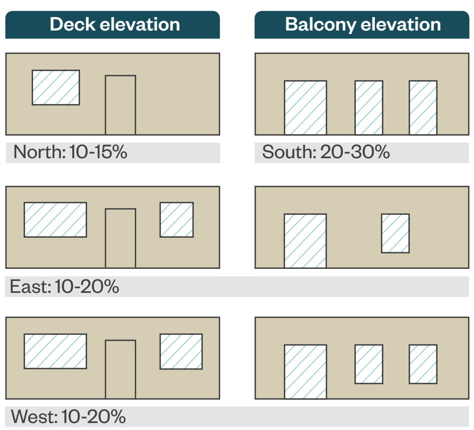
The window design should be based on orientation, daylight and summer comfort, and should work in tandem with other architectural design factors like proportion and elevational composition.

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

Window area guide (% of wall area)

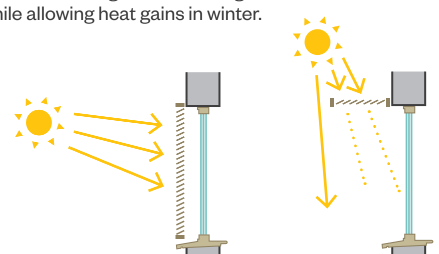
The glazing-to-wall ratios are a key feature of Passivhaus design. It is important to minimise heat loss to the north (smaller windows) while providing sufficient solar heat gain from the south (larger windows).

Consider which way a dwelling faces. It is much easier to design smaller windows facing access decks and larger windows facing balconies. Therefore, try to orientate homes accordingly.



Solar shading

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



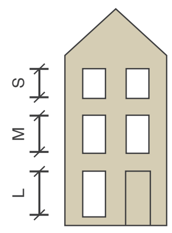
EAST/WEST: East/west orientations have a higher overheating risk due to low-angle sun. Reduce glazed areas and include shading on the west, e.g. with shutters.

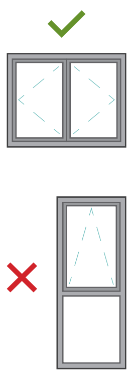
SOUTH: High angle sun can be controlled using horizontal shading or balconies above windows.

4 Elevations to balance heat gain, heat loss and daylight

Recommended starting points for window proportions:

Reduce window areas up the façade
Consider reducing glazing areas higher up the building where there is more daylight available and less overshadowing from neighbouring buildings.



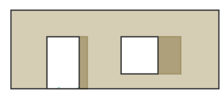


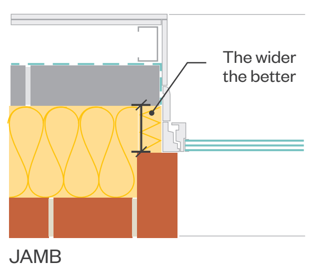
Horizontal works better than vertical
Wider, shorter windows:
- Improve daylight distribution in rooms
- Moderate overheating risk and are typically easier to shade
- Increase openable area for ventilation
- Provide increased privacy to bedrooms.

Local context or other design factors may mean this optimal approach is not always possible.

Consider how windows open for effective ventilation. Side hung provides a larger opening area than top hung. Inward opening is easier for residents to clean than outward opening. Consider clashes with internal or external shading devices.

Trick the eye
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.





Window detail
Position windows so that they are tied back to the inner structural leaf. The frame should mostly sit in the insulation zone to reduce thermal bridging.

The installation details can hide much of the frame to give a slim appearance.

Other Passivhaus window considerations:
- All windows must be triple glazed
- Increase the pane-to-frame ratio by avoiding transoms and mullions - these will drastically reduce thermal performance.
- Triple glazing is heavy – consider the size of openings. Maximum opening width typically 700mm and maximum opening height typically 1,600mm (excluding glazed doors)
- Consider alternative window reveal details that may or may not include brick returns.

Ventilation

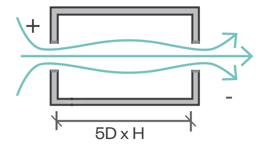
Effective ventilation is vital for ensuring good indoor air quality, the ability to mitigate heat build-up and to remove excess moisture. Homes should include background and purge ventilation:

- Background ventilation should provide a constant rate of ventilation throughout the day and across the seasons. All homes will need mechanical ventilation with heat recovery (MVHR) for background ventilation.
- Purge ventilation provides bursts of fresh air to rapidly cool or renew the indoor air, typically achieved with openable windows.

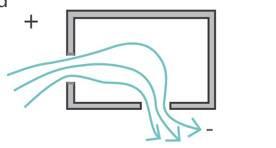
5 Natural ventilation

All habitable rooms should have openable window(s).

- Dual aspect homes allow for cross ventilation – the most effective form of natural ventilation, particularly when windows are on opposite sides. This should always be the preference. Single aspect homes are the least effective at ventilating and are at risk of overheating.
- Always provide multiple openings, maximum free area and different sizes, to allow the occupant to control their environment.

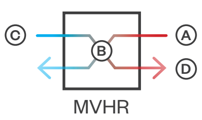


Cross vent
Most effective



Adjacent wall vent
Alternative to cross vent

6 Mechanical ventilation with heat recovery (MVHR)



How an MVHR unit works

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

The heat recovery can be automatically bypassed to provide ventilation without noise or security issues.

Utility cupboard size

A full height services cupboard is typically 800 x 800mm. To include space for a washing machine or alternative building services strategy, consider increasing it to 1,400 x 800mm.

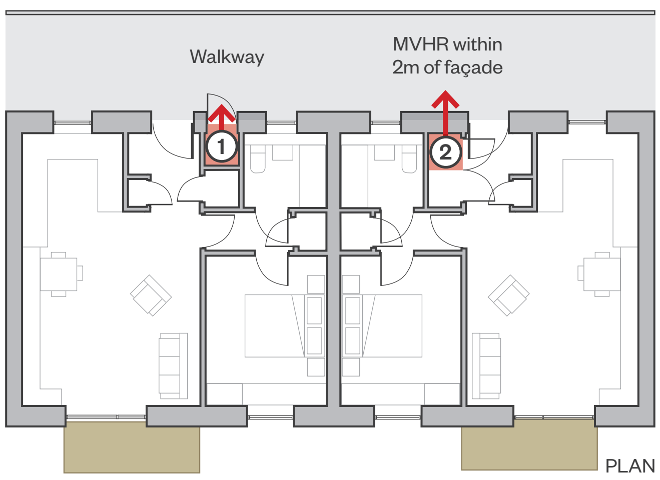
A location for a hot water cylinder could be allowed for in each flat to give the most flexibility with heating and hot water design. For one bedroom flats, this can fit under the MVHR. Allow 650 x 650mm for a cylinder.

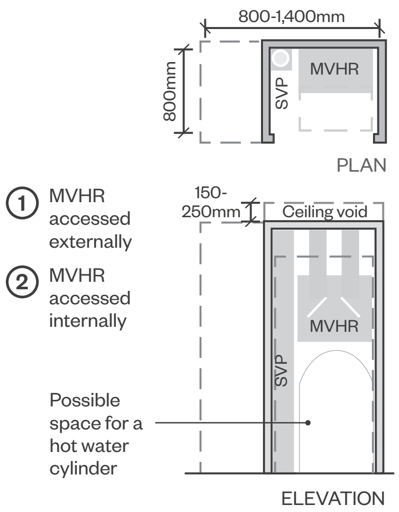
MVHR ducts will be distributed in the ceiling. Allow a minimum of 150-250mm distribution zone above extract rooms in particular (kitchens and bathrooms).

Utility cupboard position

MVHR units 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 meet Passivhaus requirements. They must not be located in a bedroom or living room.

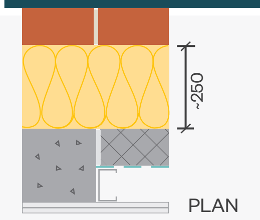
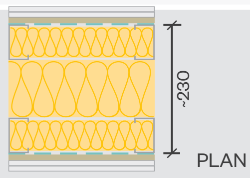
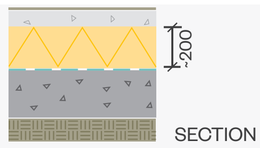
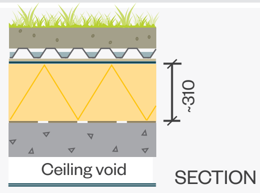
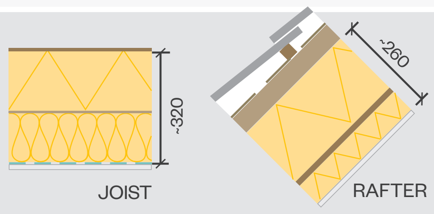




Thermal performance

7 Highly insulated building fabric

U-values 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.

Element	Target U-value (W/m².K)	Approx. total thickness	Example element build-up and comments
External walls (incl. separating walls to bin/ bike stores and plant/sub-station)	0.13-0.15	550-600mm	 • Approx. +250mm mineral wool insulation • Keep structure clear of the insulation zone • Reduce number of masonry supports where possible; ensure wall ties and masonry supports are included in U-value calculations • Full fill insulation may not be suitable in exposed locations or at height.
Separating wall (e.g. dwelling/ corridor)	0.16-0.18	325-425mm	 • Approx. +230mm mineral wool insulation • Standard dwelling to dwelling party wall constructions can also be used between dwellings and unheated corridors inside the thermal envelope.
Ground floor	0.08-0.10	150-250mm (insulation)	 • Approx. +200mm insulation • Insulation thickness depends on the area-to-perimeter ratio of the floor.
Exposed soffit	0.13-0.15	640-870mm	• Approx. +150mm mineral wool insulation to soffit of bin/bike stores and other cold spaces.
Flat roof	0.10-0.12	1,000-1,100mm	 • Approx. +310mm insulation • Insulation thickness remains the same with or without the green roof.
Pitched roof	0.10-0.12	390-450mm	 • Insulation varies for rafter or joist level insulation • Form factor of the building increases where vaulted ceilings are used.
Windows	0.8-1.00	Triple glazed	• Always use pane and frame combined U-value • Use a g-value of 0.5 to balance solar gain and solar control.
External doors	1.00	-	• No letter boxes through the thermal envelope.

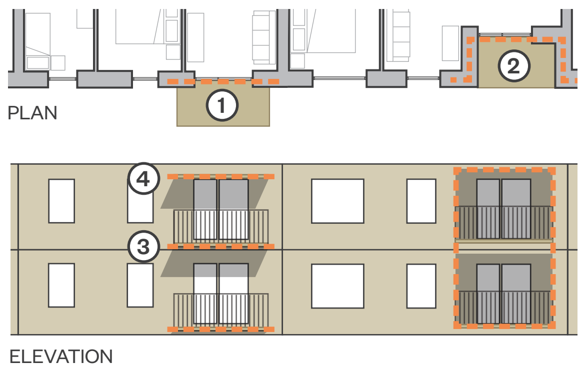
Notes:
1. *Always get U-values calculated for your construction build-up*
2. *Check that all elements in the calculation match your element build-up.*

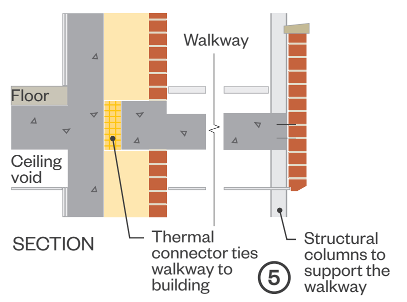
Simplify the thermal envelope

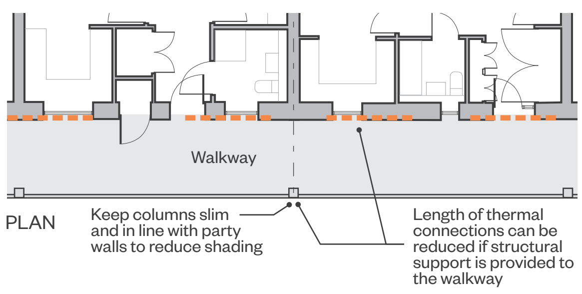
8 Balconies and access walkways

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 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. Access walkways should be structurally supported and tied back to the building, rather than cantilevered. This reduces the impact and cost of thermal connectors. However, the structure should be lightweight to avoid heavily shading the façade.

Length of potential thermal bridge



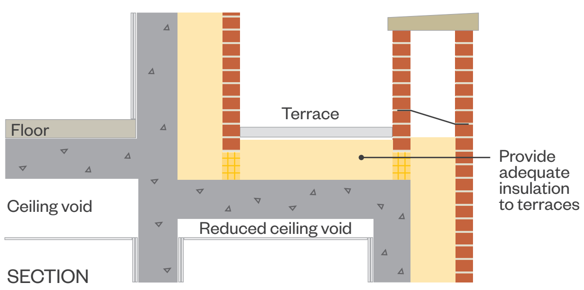




9 Overhanging structure and terraces

Avoid overhangs or undercrofts where possible. When they are needed, make sure they include space for insulated structure to support the façade above.

Try to insulate terraces with as much insulation as the main roof. This may mean using a stepped slab and/or increasing the floor to ceiling height of the building on that storey, to accommodate the extra depth of insulation.



10 From Passivhaus to zero carbon

By designing the building to meet Passivhaus, you have taken a significant step towards achieving zero carbon. This is because the building envelope is already so energy efficient that only very low levels of space heating are required. There are only two more key steps needed to achieve net zero operational carbon:

Use a heat pump

The preferred heating technology to meet zero carbon is a heat pump. There are lots of different types and arrangements to consider. To leave the most flexibility, a location for external fan units should be allowed.

Design the roof for photovoltaic panels (PV)

Prioritise asymmetric south-facing or east/west roof pitches for maximum PV energy generation. Keep roof parapets as low as possible or keep PV away from parapets. Place roof plant to the north to avoid overshadowing.

After RIBA Stage 2

Passivhaus is a construction standard. Certification relies on the building being designed so that it can meet the criteria. Verification of the building's performance is carried out upon completion. A non-certified project cannot be called Passivhaus as construction quality has not been verified.

Checklist for design team

This Easi Guide covers some of the early design decisions required to ensure Passivhaus certification is possible. However, Passivhaus design does not stop there – below is a checklist of actions following RIBA Stage 2. These are in addition to what designers are typically used to doing.

RIBA Stage 3

- ☐ Mark-up of **insulation line** on all plans and sections
- ☐ **Thermal bridge workshop** including the structural engineer for columns, masonry support, etc.
- ☐ Define airtightness strategy and identify **airtightness line** on all plans and sections
- ☐ **MVHR layout** including duct distribution and measurement of intake and exhaust duct lengths to external walls for **sample dwellings**
- ☐ Measurement of **heating and hot water pipe lengths** for **sample** dwellings
- ☐ Client to **appoint a Passivhaus certifier** to review the Passivhaus designer's work.

RIBA Stage 3+

- ☐ **Detailed build-ups** of all external elements including thickness and conductivity of all materials
- ☐ **Detailed U-value calculations** (including masonry support system, etc.)
- ☐ Identification of all **thermal bridge junction types** (e.g. parapet A, parapet B)
- ☐ **Thermal bridge calculations** for a selection of the most important junctions
- ☐ **Definition of airtightness testing** requirements for contractor.

RIBA Stage 4 *(in addition to Stage 3+)*

- ☐ **Development of junction details** for window and doors
- ☐ **Review of airtightness line** on each drawing and identification of airtightness requirements for service penetrations
- ☐ **Thermal bridge workshop** to review thermal bridge lengths and Psi-values
- ☐ **Thermal bridge calculations** to determine Psi-values for all junctions
- ☐ **MVHR layout** including duct distribution and measurement of length of intake and exhaust ducts for **all homes**
- ☐ Measurement of **heating and hot water pipe lengths** for **all homes**
- ☐ Preparation of detailed **Passivhaus tender requirements**
- ☐ Liaison with **Passivhaus certifier** for design check.

RIBA Stage 5

- ☐ Introduction to **low energy construction workshop** on-site
- ☐ Site manager and **team training on construction quality** requirements covering insulation and airtightness
- ☐ Preparation of **Passivhaus toolbox talk material** for site team inductions
- ☐ Regular Passivhaus construction quality assurance **site visits** (depending on the size of the scheme – at least six) combined with regular visits
- ☐ Preparation of associated Passivhaus construction quality assurance **site visits reports and feedback** to construction team highlighting key actions required
- ☐ Develop existing **site quality tracker** in include Passivhaus items and update regularly
- ☐ **Leak finding airtightness tests** at first fix
- ☐ **Second airtightness test** pre-completion
- ☐ Witness **commissioning of MVHR** systems
- ☐ Witness **commissioning of heating system**
- ☐ Stage 5 **PHPP model** of each building leading to the final 'as built' PHPP model
- ☐ **Check compliance** against Passivhaus requirements
- ☐ Liaison with **Passivhaus certifier** for construction check
- ☐ Preparation of **final Passivhaus compliance** report.

RIBA Stage 6

- ☐ Provide **simple instructions for user** (e.g. sticker on MVHR for filter replacement)
- ☐ Fixing of a **Passivhaus plaque** to the scheme to demonstrate the building(s) met the standard.

The Passivhaus 'designer' and 'certifier'

On every Passivhaus project that aims to be certified there will be a 'designer' and an independent 'certifier'. The designer's job is to support the design process and carry out Passive House Planning Package (PHPP) modelling at each stage. A Passivhaus certifier will need to be appointed pre-tender to check the designer's model and confirm compliance.

Consider the construction contract

The type of construction contract matters for a Passivhaus scheme. This is because the quality of the build needs to be high. Therefore, consider whether the use of a traditional contract may have more advantages over a Design and Build contract. Under a Design and Build contract, the Passivhaus certifier will remain client side and the designer will be appointed by the contractor.