5

Building services

Alan Clarke

Summary

Whilst building fabric is the key to Passivhaus performance, it is important to pay attention to building services. Mechanical ventilation with heat recovery (MVHR) poses the most challenges but it is also important to design heating systems appropriate to the level of heat demand so they run smoothly and economically. This section looks at the principles of building services design.

Introduction

There can be a temptation to think of a Passivhaus as an opportunity to deploy the latest renewable heating systems. However, having put the effort into a high performing fabric, there is little need to spend a lot on heating systems, and the heating demand is so small that extra investment in expensive heat sources may not be worthwhile. The challenge is to deliver systems that don't cost a lot, respond well to small and erratic heat demands, and are still efficient in terms of primary energy and carbon emissions.

On the other hand inexpensive ventilation systems do not usually meet the performance requirements needed for Passivhaus. The importance of heat recovery efficiency in the PHPP energy model means that high quality Passivhaus certified components are justified, and the expense can be offset against additional fabric insulation costs that a poorer MVHR would require.

Ventilation

The performance of the ventilation system is considered an integral element of the primary Passivhaus heating demand calculation, though the rest of the services are not. You can think of this as being because the main intake and exhaust ducts, carrying cold air, actually form part of the building's external envelope. So in keeping with the emphasis on compact form, the designer needs to be aware of these ducts and how to make them as short as possible at an early stage in design.

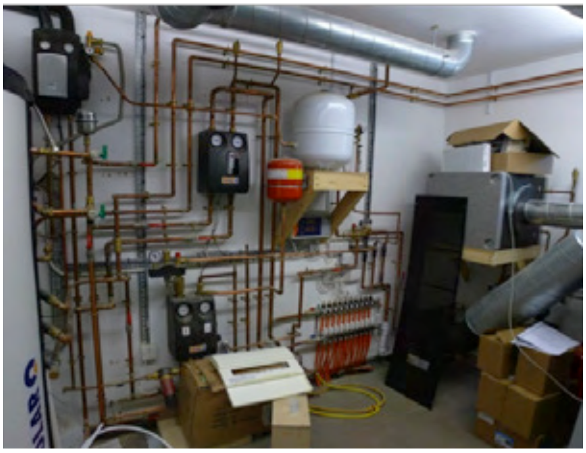
The impetus for using MVHR may have come from the opportunity for heat recovery but now we recognise that the main benefit of these ventilation systems is basically good ventilation. The Passivhaus standard sets detailed criteria for airflow rates, noise levels and commissioning which, if followed, will lead to ventilation that works well. The ventilation section of this guide provides specific details about designing ventilation to the Passivhaus standard.

Heating and hot water

A Passivhaus does need some heating – this is implicit in the standard, which is in terms of annual heating demand or peak heat load, after taking account of solar and internal heat gains. However, the amount of heating is very small – much less than a standard new building, and far less than the 20th Century buildings our heating systems have developed in.

It should be possible to heat a Passivhaus by heating the ventilation supply air, but this doesn't mean you should do it. There is often a mismatch between where you want air and where you need to supply heat, so it can be easier to separate them. Also neither boilers nor heat pumps are well suited to supplying the steady low level of heating power required by air heating.

In fact the heating system is one area where you can reduce costs compared with a conventional building and still retain conventional suppliers and technologies – simply use a gas boiler but with fewer and smaller radiators.



An unfinished plant room. Photo: Nick Grant

Larch House, Ebbw Vale, using both PV and Solar thermal
Photo: bere:architects

Heat pumps are also well suited to Passivhaus – radiators 'oversized' to work at heat pump temperatures (around 45C) are not large or expensive thanks to the low heat load, and there is no risk of the heat pump being unable to meet the demand in cold weather. Thanks to the minimal heating requirements of Passivhaus it makes sense to favour air source heat pumps + radiators over the ground source + under floor heating combinations, which are a little more efficient but at high capital cost.

Biomass heating with pellet boilers is not so well suited to Passivhaus – basically the heating demand is just too small, and the boilers aren't good at operating continuously at such low output. This could be managed with a large thermal store – but again the expense isn't justified by the minimal heating demand.

do

- **think about MVHR location at an early stage**
- **make sure the MVHR is easy to access for filter changes**
- **get a full ductwork design done in time to integrate with the architectural design**
- **have the system commissioned on completion – you need to do this for certification**
- **allow for some sort of heating system, but make it cheap and simple**

Renewables

Traditionally solar thermal has been a popular choice for Passivhaus designers. The PHPP energy model allows solar thermal input to reduce the total primary energy demand, which can allow simpler direct electric input as the back-up heat source. However big drops in the cost of solar photovoltaic (PV) generation has changed the landscape and solar thermal is becoming a rare option.

Managing power from solar PV is a fast developing field – the starting point is controllers which use 'surplus' power to directly heat hot water, but newer systems are able to manage domestic appliances and heat pumps, running these preferentially when there is a high level of PV generation.

The Passivhaus Institute is moving towards including PV generation in Passivhaus certification. This will be in the form of new classes Passivhaus Plus and Passivhaus Premium. These standards require the same fabric standard as any other Passivhaus plus reductions in the primary energy demand compared with the existing Passivhaus standard, in order to address the problem with 'net zero energy' buildings, which generate a surplus of solar power in the summer and claim it back in the winter.

don't

- **think you have to heat via the air supply**
- **get carried away with expensive heating systems – they won't be used enough to be worth it**
- **expect to just use direct electric for space and water heating and stay within the Passivhaus primary energy limit**
- **expect that the MVHR will distribute heat from a heated room to an unheated room – it won't**

1 Mechanical ventilation heat recovery (MVHR)

Alan Clarke

Introduction

An MVHR system has a ventilation unit with two fans: one draws outside air in and supplies it to bedrooms and living rooms; the other extracts air from kitchens and bathrooms to exhaust to outside. Inside the unit there is a heat exchanger which transfers the heat from the outgoing air to the incoming air without any recirculation of the air itself.

MVHR

The fans run all the time, but can be switched to different speeds – usually low, normal and boost – and these rates are adjusted at commissioning to suit the individual house. The unit includes filters which remove dirt (and insects) from the air supply.

A system of ducts is needed to distribute the air from the ventilation unit to and from the rooms in the dwelling, and there are also ducts between the unit and outside to bring in fresh air and exhaust stale air.

Large Paul MVHR unit. Photo: Conker Conservation

Paul MVHR Unit with optimised duct lengths (pre-insulation). Photo: Alan Clarke

System sizing and flow rates

There are set criteria for working out how much air to supply in a Passivhaus; these are provided in the manual for the Ventilation Final Protocol Worksheet, which is supplied with PHPP. Supply air and extract air are worked out differently, but when the system is running they must be equal, i.e. in balance.

Supply air is set at $30m^3/h$/person – this should be calculated using the actual number of people expected to live in the house, rather than the default figure calculated by PHPP at $35m^2$/person. For under-occupied houses (>$40m^2$ per person) the backstop rate is 0.3 ACH. This gives the standard airflow rate, which is usually set as the middle fan speed.

Extract rates are normally based on individual wet rooms: $60m^3/h$ for a kitchen, $40m^3/h$ for bathrooms and utility rooms, and $20m^3/h$ for a WC.

The total extract rate is usually higher than the supply rate – the difference is dealt with by running both fans at the higher rate when cooking or bathing requires extract. The design 'boost' rate is either the 'standard' rate + 30% or the total extract rate, whichever is larger.

Confusingly, the PHPP calculations of the nominal rate are different: PHPP first sets the maximum flow as the larger of the supply and extract rates, as calculated above, and then sets the standard rate at 77% of this figure. The implications are that for more densely occupied houses the per-person rate will be lower than 30m^3/hr/person and for houses with large numbers of bathrooms the per-person rate will be higher.

It's advisable to default to the manual and the 30m^3/h/person standard rate and adjust extract rates up or down to give a boost of +30%-40%, provided that the building regulations Part F boost extract rates are still maintained.

When it comes to deciding air flow to each room the basic rules are bedroom supply of at least 15m^3/h/person, so 30 m^3/h for a double bedroom, and the remainder is available for living spaces. Dining rooms can often rely on air passing through to the kitchen and so don't need their own supply, but this depends on the layout of a particular house. Extract rates are set according to room type but need to be reduced proportionally from the boost rate to the standard rate, so that the supply and extract rates are in balance.

The two settings for normal supply and boost extract are comparable to the Part F approach, though the backstop figure for Part F works out at 0.4 A air changes per hour (ACH) rather than 0.3. We think the Passivhaus level is adequate since MVHR actually provides a significantly higher fresh air rate in bedrooms and living rooms, and the research basis for Part F was in window-ventilated houses which don't benefit from fresh air being supplied just to these rooms. The lower figure for Passivhaus also helps avoid over-drying of internal air in winter.

Passivhaus design also allows for a 'low' fan speed, normally 30% lower than the standard rate, which can be used when the house is unoccupied.

Ventilation unit and ductwork

Ventilation unit location is very important to both the efficiency and also the long term usability of the system. Ducts connecting to outside contain air at the outside temperature, so are effectively outside walls – we use insulated ducts but can't possibly insulate them to the standard of the wall. The ducts therefore need to be as short as possible, basically the unit needs to be located adjoining an external wall, or failing that, within 2m of one. It is possible to install the unit in a frost free location outside the thermal envelope, e.g. a garage, but the connecting ducts still need to be as short as possible and of course the external terminals have to be outside the garage.

Access is needed to change filters (every 3-6 months, depending on how dirty the outside air is), so you should be able to walk up to the unit and reach it without needing a ladder. Some units are too noisy to have in a living room or bedroom, so the ideal is a utility room or WC/cloakroom. Allow space for ducts and ancillary equipment when allocating space – look at previous installations for guidance.

Condensate drainage is needed from the ventilation unit – this should be to the internal soil pipe system via a trap and not just straight to outside, otherwise it could freeze and the unit would flood.

External terminals can be close together – often vertically one above the other with exhaust 600mm below intake is a good solution to minimise wall use on a narrow frontage house. The position of the intake terminal is important for air quality – avoid locating near smells or pollution, e.g. bins or car park, and avoid intake through the roof in order to avoid bringing in hot air in summer – even north roofs can get hot. Put the intake 2m or more above ground level to minimise intake of particulates. It is better to have the exhaust on the same wall as the intake, to minimise impact of wind pressure difference. Using a roof exhaust causes problems of condensate from the damp exhaust air collecting in the duct and needs special drainage.

Ductwork can either be rigid – normally steel – in a branched configuration, or newer 'semi-rigid' systems which use plastic ducts that can be bent round corners, but still have a smooth inner bore. For the latter, the ducts are arranged radially running one or two to each room from supply and extract distribution manifolds. 'Flexible' ductwork, like old tumble drier hoses, is not acceptable – it gets squashed and has a high resistance to airflow. All distribution ductwork has to be within the airtight thermal envelope – no exceptions.

LEFT: Well-designed duct runs underneath the OSB air barrier. Photo: Alan Clarke

Ductwork size is determined initially on air velocity to avoid regenerating noise, and the requirement is <2m/s generally, and up to 3 m/s for the main ducts at the MVHR and connections to outside. With these velocities the ductwork system will have low pressure loss, though for larger houses and non-domestic projects, full design is advised (with specialist ductwork design software – the system supplier should be able to do this) to ensure the system remains balanced despite longer duct runs. Higher pressure loss increases fan energy consumption and the test figures for PHI certified MVHR units only apply up to a maximum system pressure of 100Pa. This should only be exceeded in large non-domestic projects when additional calculation is needed to determine the fan energy usage in PHPP in accordance with actual system pressure loss.

Noise control is needed to make the system unobtrusive – noisy systems get turned down or off. Include proper silencers on supply and exhaust – these are big (900mm long and 100mm larger diameter than the ductwork) so if possible fit them between ceiling joists. Branched systems may also require cross-talk attenuators on the supply to prevent noise transmission between rooms via the duct.

Spiral wound galvanised steel – Efficient, robust, cleanable. Photo: Alan Clarke

The Passivhaus ventilation protocol worksheet gives design figures of 25 dB(A) in living and bedrooms and 35 dB(A) in the room containing the MVHR fan unit. These figures are used to calculate attenuation required – they are too low to accurately measure, at least during the day on a busy building site. Once the system is running you shouldn't be able to hear the ventilation in bedrooms or living rooms.

Room terminals are different for supply and extract, and there are different terminals for wall supply, directional ceiling supply, and all-round ceiling supply. The position in the room depends on the terminal type: directional terminals are often used to throw air in from the doorway; standard terminals need to be near the middle of the room (but avoid locating over beds) – in front of windows is usually good as the terminals are then unlikely to be obstructed by high furniture. Extract terminals can be put on a wall or ceiling; always put these on the far side of the room from the door.

In housing, door undercuts are the normal way to allow air to flow out of supply rooms and into extract rooms. The minimum undercut is 10mm above final floor finish.

Installation, commissioning and maintenance

Always use a fully designed ductwork system – for domestic ventilation this would usually be done by the system supplier, however they may charge for this. Use the ductwork and fittings specified and don't allow short-cuts with flexible or shallow plastic ductwork.

Cleanliness needs to be maintained during construction. Any dirt in the ductwork system will be blown into the house later. Keep ductwork covered before use and cover open ends of ductwork during construction. Do not run the fans at all until after the final clean of the house to avoid drawing dust etc into the ductwork.

Commissioning is the job of setting the system up with the correct flowrates. This can only be done once the house is clean. Traditional branched systems need to have the flowrate for each room adjusted at the terminal, though good ductwork system design will give required settings (in mm). Semi-rigid systems may come designed with specific flow regulating inserts for the duct to each room. It is still necessary to check the flow at each terminal.

Hand over the system with a description of the system, demonstration of how to operate the controls and how to change filters. Also provide information on where to get replacement filters and written and illustrated instructions on how to change the filters when the time comes 3 or 6 months later.

The primary maintenance requirement is changing filters. Some ventilation units maintain a constant air flow rate when filters get clogged, but in so doing the fans get noisier. Older or cheaper systems just supply less air. So regular filter changes are important. Write the date of install on the filter. Most control units have a filter-change indicator but this is based on number of days.

It is an advantage if occupants can periodically check the system: some systems are so quiet that occupants may not notice if the fans stop running. Over a few years dust builds up on extract valves. These can be removed and cleaned, being careful not to change airflow settings or mix valves between rooms. Terminals should be removed for redecoration, but must be labelled by room if more than one is removed.

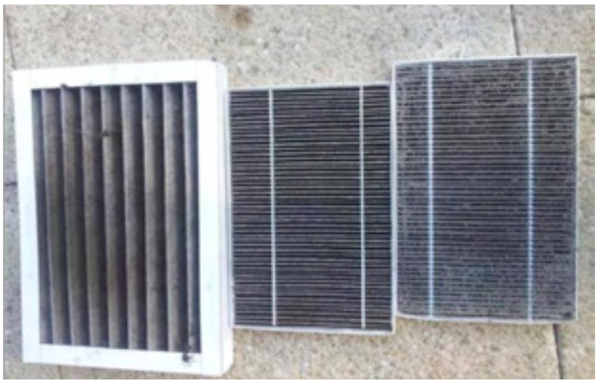
do

- make space for the ventilation unit at the start of the design process
- provide routes for ducts – think of octopus tentacles not just typical section drawings
- fill in the Ventilation worksheet before completing the PHPP
- use a PHI certified ventilation unit
- get a complete ductwork design before starting installation
- use a commissioning specialist familiar with Passivhaus systems

don't

- just stick the ventilation unit in the loft
- omit silencers
- accept shoddy ductwork installation

BELOW: Filters before and after use
Photos: Andrew Farr



Case Study Knight's Place

Knight's Place is a certified, social housing development of 18 one and two-bedroom apartments, designed by Gale & Snowden Architects for Exeter City Council.

With MVHR an integral feature of all Passivhaus developments, Zehnder's ComfoAir 200 whole house heat recovery system was specified for each apartment.

As the heat loss in each flat is so minimal the heating requirement is met during winter extremes via a small air heater in the supply air duct just after the heat exchanger.

Another key benefit of the CA200 is its filtered bypass, which circumvents the heat recovery mode during warmer months. Ventilation is provided continuously without warm and humid air entering unnecessarily which can assist in reducing summertime overheating.

When tested at the end of a two year monitoring study, Knight's Place apartments maintained a comfortable temperature of 21°C year round for residents, with minimal heating required and low running costs.

2 Heating and hot water

Alan Clarke

Introduction

A Passivhaus building can in theory be heated via the fresh air supply – that is after it is heated to around 50°C. This idea of doing away with a conventional heat distribution system helped define the Passivhaus standard, but isn't necessarily the best choice. Any heating system can be used – radiators, underfloor heating, split system air conditioning, wood burning stove and you can use a gas boiler, a heat pump or district heating. Direct electricity for both heating and hot water is not normally possible because electricity's high primary energy factor means this usually exceeds the Passivhaus primary energy limit of 120kWh/(m^2.a).

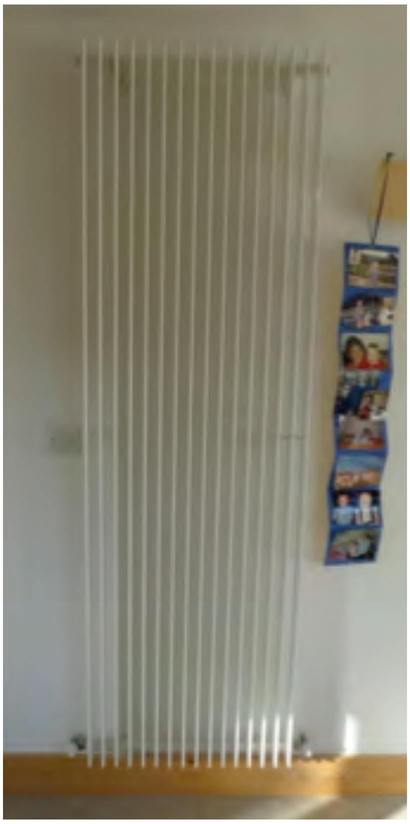
Heating

It makes sense to think of the heating system as primarily providing hot water, plus heating as and when needed. The efficiency of the hot water system, ie minimising losses from storage and distribution, is significant both in terms of energy use and summer overheating. In PHPP losses that contribute to heating are considered to be part of the heating demand and not the hot water demand – so in fact the heating system itself can be providing significantly less than the calculated 15kWh/(m^2.a).

Heating loads

PHPP works out an overall heat load, in terms of watts and W/m^2. This gives a continuous heat load – ie, assuming the heating is on 24/7, and is aimed at seeing if heating via the air is possible. The numbers are finely balanced, which may be lovely in theory but doesn't always make for a robust and easy to live with heating system. For other heat distribution methods, such as radiators, you have the option to turn heating off at night, and warm up relatively quickly when cold. An allowance for extra capacity should be included – as a rule of thumb size Passivhaus heat emitters at 20W/m^2 (or in other words at 200% of design heat loss).

For radiator systems you can use a simple room by room steady state heat loss model. You can read off the effective ventilation and infiltration rate from the PHPP sheet – a ventilation rate of 0.5 ACH and 90% heat recovery is effectively 0.5 x (1 – 0.9) = 0.05 ACH.



Radiators can be an excellent match for Passivhaus if sized correctly.
Photo: Alan Clarke

Heating systems

Air heating is the defining method for Passivhaus, in theory minimising costs. In practice there are a lot of reasons for not using air heating:

- **A particular room's demand for heat and fresh air are rarely in balance – bedrooms need plenty of fresh air but little heat, bathrooms get no fresh air but need heat.**
- **Warm air rises to higher floors – this is not normally a problem but if the heat input to lower floors is strictly limited (by rate of ventilation) then it can be an issue, especially with more than two storeys.**
- **The air can only absorb a very limited amount of power – several times less than the minimum output of a gas boiler, so some form of buffering is needed if a boiler is used.**

Radiators make for a cheap heating system, but are also an excellent match for a Passivhaus. Thanks to triple glazed windows you can put them where you like in a room as there are no downdraught comfort issues. Individual room control with Thermostatic Radiator Valves (TRVs) allows the system to respond to solar and internal heat gains, which provide a far greater fraction of the heating than in a conventional building.

Radiators can also provide buffering for the minimum output of a gas boiler or heat pump: the thermal mass of the radiators allows the boiler flow temperature to rise gradually even though the boiler may be generating 4 or 5 times the amount of heat the building needs. Then when the boiler stops firing the radiators continue to release heat to the rooms.

Warm radiators generate convective air movement, which helps move heat around a house. This and the high levels of insulation mean you don't need radiators in every room.

Underfloor heating certainly works in a Passivhaus, but is an expensive option since it is a radiant source and you need to install it in every room you want to be warm. This then means that the system can be far too powerful for the heat load – and needs careful control to avoid overheating. If you can keep the floor temperature down to a degree or two above room temperature however, the heat output will be self limiting – once the room is warmer than the floor it will stop heating the room.

Heating sources

Gas boilers are the default heat source in the UK and can easily be used in a Passivhaus. Combi boilers provide hot water on demand, and as such have high kW output so tend to need additional radiator capacity to buffer this. System boilers work with a hot water cylinder, so the boiler will generally be the smallest size available.

To use deliberately oversized radiators (see image, left) and yet avoid overheating, the boiler controls need to be able to run the heating system at a lower temperature than traditional, and yet still provide hot water. Combi boilers do this by default, but system boilers usually require some sort of add on diverter valve arrangement, along with the manufacturer's 'intelligent' controls – all wired quite differently than conventional mid position valves.

In areas with no mains gas there is the alternative of LPG stored in tanks or large bottles. LPG boilers are essentially the same as those used with mains gas, the only downside is higher fuel cost and the space requirements for gas storage.

MVHR with heat pump in small services room
Photo: Kirsty Maguire Architects

Air source heat pumps are a practical option for a Passivhaus. Modern pumps are able to heat hot water without needing direct electric boost (immersion heater), which is important considering that hot water forms the majority of their annual usage. This does mean that the performance may be lower than advertised, and remember that some of the heating demand is also met by hot water losses too.

PHPP now has a detailed section for heat pumps which uses the test data normally quoted by manufacturers for a range of operating temperatures, plus the heating and hot water loads of the building to more accurately estimate the electricity consumption and performance (COP) of the heat pump.

Underfloor heating is normally recommended for heat pumps but, remembering that only 25%-40% of the heat pump output is going to the heating, this may not be worthwhile. Radiators oversized to run at 45°C will be nearly as efficient, plus easier to control and cheaper.

Ground source heat pumps are also possible, though the advantage of using the ground as a low grade heat source in winter is reduced since heating is a small proportion of the total demand, and summer hot water efficiency will be lower than an equivalent air source heat pump. So the high cost of installing ground collectors is not normally justified.

Wood burning stoves can be used, but require careful selection to ensure safe operation with an airtight mechanically ventilated house. There are certified 'room air independent stoves' available from Germany and Austria, but they are expensive and hard to find. Alternatively a stove with an external air supply can be used in conjunction with a differential pressure switch to stop the ventilation in the event that it is depressurising the house (due to either supply fan failure or duct blockage).

A cheap, and sensible, approach is to use a stove purely as a room heater, downstairs in a small open plan cottage – that way it can heat the whole house. A hot stove distributes heat via convection very well. The cost of installing a boiler stove with thermal store, associated controls and heating distribution will never pay for itself in a typical Passivhaus, where a wood burning stove is used as a room heater, hot water is normally provided by electricity and solar energy, or a gas boiler.

Hot water systems

Hot water often uses more energy than heating in a Passivhaus so it pays to concentrate on designing an efficient system. Use the DHW sheet in PHPP at an early stage in design, since the losses here are included in the summer overheating calculation

Hot water heat losses fall into three categories: cylinder; continuous (secondary) circulation; and draw-off dead leg. In addition there is the primary heat loss between the boiler or heat pump and the cylinder. To convert the manufacturer's hot water cylinder heat loss data in kWh/24hrs into Watts, multiply by 1000 and divide by 24.

Circulation loss only applies if you have a pumped hot water loop – not normally necessary in houses. If you do have one, then insulation levels and pipe length are the important factors to optimise.

Draw-off losses represent the cooling down of the hot water pipe and its contents after each period of use. Here insulation is not significant – the pipe will cool down anyway: the important factors are pipe diameter and length. Shorter pipes have the advantage of lower pressure loss, which means it may be possible to use smaller diameter pipework. See AECB water standards guidance for details.

Cylinder location is the key to efficient hot water distribution. It needs to be as central to the various hot taps as possible in order to minimise the total draw-off pipe length and avoid the need for secondary circulation. A house layout which groups kitchen, utility and bathrooms in one area is also very beneficial. To minimise the primary pipework heat loss the boiler or heat pump also needs to be as near to the cylinder as practical.

Combi boilers are an alternative in smaller dwellings. Hot water output rate is limited so only use these in single bathroom dwellings. The advantage is that you get rid of the bulky hot water cylinder, connecting pipework and associated heat losses. The only combi boilers which completely avoid hot water storage are gas (or LPG) powered. Oil combi and heat pump combi boilers actually have a hot water tank built in.

BELOW: Passivhaus reduces the need for services!
Photo: Nick Grant

don't

- spend a lot of money on a biomass boiler or bore hole heat pump system
- expect that a 100% electric heating and hot water system will comply with the primary energy limit for Passivhaus certification

Thermal stores are an alternative approach to hot water storage where hot water is generated on demand via a heat exchanger. Don't use these unless you have to – say for a wood burning boiler. The store has to be kept at a significantly higher temperature than a normal hot water tank, leading to increased heat loss and reduced boiler efficiency (never use with a heat pump). And in the end the hot water performance in terms of flow rate and temperature is generally worse than the standard hot water cylinder.

ABOVE: Water tank located in a cupboard. Photo: Alan Clarke

do

- use a cheap and simple heating system – the investment belongs in the building fabric
- consider radiators as your first option
- arrange the layout to keep hot water outlets in a reasonably compact form
- put the hot water storage (or combi) in the same area
- chose heat pumps that provide good hot water performance rather than heating
- fill in the PHPP DHW section before looking at overheating

3 Solar thermal and photovoltaics (PV)

Alan Clarke

Solar thermal

Solar thermal has traditionally been the cheaper and lower technology way to harvest solar energy. The heat can only be used in the house where it is installed and PHPP recognises this as contributing to reduced primary energy consumption because less fuel is needed for water heating. Systems need to be carefully designed to provide as much useful hot water as possible whilst avoiding over heating in summer.

Photovolvatics

In the past photovoltaic generation was very expensive thanks to the cost of the high tech semiconductor factories needed to make the collectors. Now mass production has brought costs down to a level where PV makes economic sense.

In PHPP solar PV is now modelled but does not show as a contribution to primary energy – the rationale is that PV systems are connected to the grid, and electricity not used in the house is exported for use elsewhere and there is no direct relationship with the energy used in the dwelling. Also historically the generous subsidies for PV and resultant trend for PV to be installed by third parties as a financial investment has led to the view that PV is not tied to a particular building in the same way as solar thermal.

The new Passivhaus plus energy standard includes PV generation, but retains the same Passivhaus building efficiency levels as the standard Passivhaus.

Standard domestic tariffs don't meter export of electricity so it is in the householder's interest to use as much as possible of their PV generation. Immersion heater controllers are available which divert any surplus power to an immersion heater, providing effectively a cheap solar hot water system. This isn't accounted for in PHPP or Passivhaus certification and the view is that this electricity could be exported and used elsewhere, so it isn't really free.

do

- **use MCS products and installers**
- **ensure solar thermal has regular inspection and maintenance**

don't

- **specify an over-sized solar thermal system**
- **expect PV systems to help you meet the primary energy demand in a Passivhaus**

Renewables on Denby Dale Passivhaus
Photo: Green Building Store

4 Fenestration and shading

Nick Grant

Introduction

Good fenestration design requires effort, knowledge and experience but following some basic rules of thumb can help avoid the most common pitfalls.

Orientation

Even Passivhaus windows have about eight times the heat loss of a wall but this is partly offset by solar gains. Graph 1 shows the annual energy balance per m^2 of large un-shaded Passivhaus quality windows facing the four cardinal points (building located in the UK Midlands). In practice, east and west glazing has much more solar gain than typical south glazing during summer but is difficult to shade. Conversely, simple overhangs from roof and reveals provide shading of the south from the high summer sun.

Because of the net winter gain and relative ease in controlling summer gains, domestic Passivhaus buildings are best designed with as much of the living areas located on the south as possible. This allows the building to be day-lit and ventilated with mostly south glazing.

If we follow this pattern, the south windows would tend to be larger and the others smaller. This further alters the balance in favour of south glazing, as the amount of frame is less in proportion to glass for larger panes. See Graph 2 for a real Passivhaus design in the same climate zone.

Passivhaus is not passive solar

When we calculate the net energy gain and amortise the cost of glazing over an assumed life of say 20 years, we find the cost of free solar heat through south glazing is about 50p/kWh. If the window area is required for daylight, ventilation, views and other functions then the heat really is free. If not, then extra glazing is an expensive way of providing heat!

Glazing ratios

It is possible to design a Passivhaus with lots of glazing. PHPP allows us to balance the high losses with extra gains and additional insulation. We can then design out the resultant summer over heating by adding shading in the form of overhangs and blinds. This might work in a model but in reality it is a very expensive way to meet the Passivhaus standard and it will be very difficult to regulate summer temperatures.

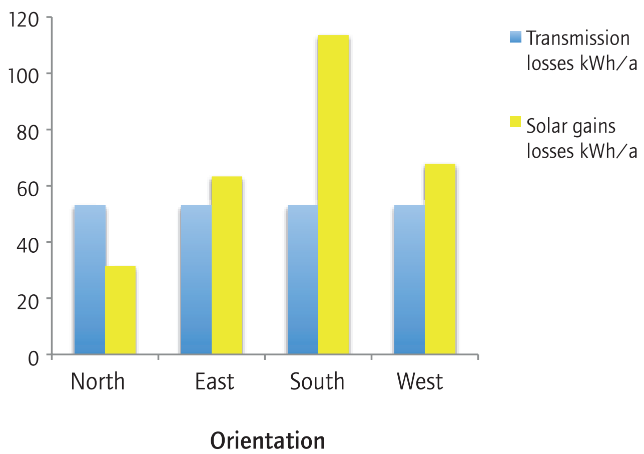
A far better approach is to design for good, but not excessive daylight, with a maximum of about 25% of the internal south facade as glazing. All other orientations should ideally have only as much glazing as is needed for views, daylight and ventilation.

As a rule of thumb total glazing area (excluding frame) of around 15-20% of treated floor area (TFA) is a good starting point for design.

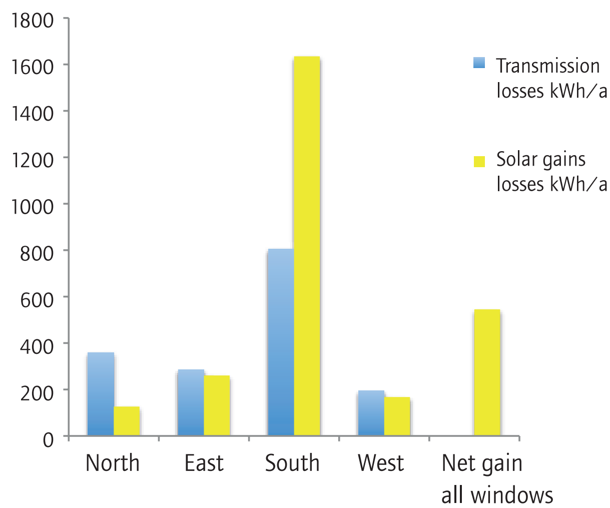
Shading

With modest glazing designed for daylight rather than maximum solar gain, it is often possible to achieve sufficient summer shading of south glazing via the existing roof overhang or window reveals.

Graph 1 Annual energy balance for larger windows



Graph 2 Annual energy balance for an actual design with larger South windows



ABOVE: Wilkinson Primary School Classroom. Photo: Architype

LEFT: River Studio Shading Photo: Marco da Cruz

To fully shade south glazing at summer solstice we need a 60° shading angle in the UK. Low sun in autumn and spring may still cause some overheating but we can open the window for cool air. On hot days in summer the outside air will be warmer than indoors so throwing open the large glass doors doesn't really help.

For hotter climates or where the glazing has been overdone, it is necessary to include external moveable shading. However, blinds and shutters are expensive, require maintenance and obscure the daylight and view that the window was installed to provide.

Internal blinds have much less impact on overheating as the heat is already in the room but have a slight benefit in that they can control glare and provide privacy.

Either inward or outward opening windows are possible but inward opening windows allow external shutters or blinds and fly screens. Note that is it very difficult to effectively shade rooflights, so large skylights can pose an overheating risk.

Rules of thumb

- Maximum south glass area about 25% of internal wall area
- Total glazing about 15-20% of TFA
- Limit skylights to about 10% of floor area for that room
- Glazing below about 850mm from the floor does little to improve daylight
- Window heads close to ceiling maximise daylight penetration (but leave room for curtain rails, binds, and ventilation opening for tilting windows)
- 2% daylight factor is a good target; higher than 4% might indicate overheating risk for that room

do

- **have at least one opening window in every habitable room**
- **design for daylight and views**
- **design for daylight quality and usefulness over brute quantity**
- **for the UK climate do try and design without the need for external blinds**
- **consider glazed doors rather than solid, for extra light and solar gains**
- **consider fly screens and security for summer ventilation**
- **use light wall colours to improve daylight without increasing overheating**

don't

- **rely on deciduous trees to provide summer shading**
- **try and heat the building with the sun**
- **over-glaze**
- **make opening window lights too large to open safely**

6

Whole-building systems

Kym Mead

Summary

A 'Whole-building system' addresses the Passivhaus criteria and performance requirements by providing all parts of the system needed to create high levels of thermal comfort and good air quality. This can ensure that the building specification has been thought about at an early stage ensuring that design and performance backstops are integral to the building conceptual design.

Introduction

Passivhaus encourages designers to address all aspects of the design at an early design stage, including the types of materials/systems that will be used. A whole-building system approach i.e. one where the materials have been pre-selected and developed into a holistic system, can help designers make their design decisions with confidence that the final outcome will meet the Passivhaus requirements. This chapter highlights the key areas that should be addressed when adopting a whole-building system approach.

Holistic design

Passivhaus encourages an approach to design which considers the building as an interconnected whole. Holistic concepts should be applied to the orientation and form of the building, as well as the design of mechanical services and fabric performance.

Designers can address all these interconnected principles/requirements through their own work, for example through their PHPP calculations. Alternatively, there are now mutliple companies that offer a 'Whole-building System' approach to achieving the Passivhaus standard. This may offer a simpler approach, especially for inexperienced designers or clients, as the system providers will have undertaken much of the work to ensure compliance with the Passivhaus standard. In addition, the systems are built in state-of-the-art factories by highly skilled technicians, which allows for closely monitored quality control without the need for mutliple on-site visits during varying weather conditions. However, they may not be suitable for all sites, designs or situations!

All whole-building systems should deliver on Passivhaus requirements, including the following principles:

Fabric U-value 0.08 – 0.15W/m^{2}K

The building fabric will probably have 200-300mm of insulation, depending on the lambda value of the insulation, but still needs carefully considered design, which will reduce heating and cooling energy requirements significantly. The design should also avoid thermal bridges, which could compromise the thermal performance of the building, although the system should help as these potential bridges should already have been considered, identified and minimised.

Airtightness

The system should achieve the target of very airtight construction, which has four advantages:

- **No draughts, and thermal comfort at lower temperatures**
- **Fabric preservation through preventing moisture ingress into walls from inside**
- **Energy saving**
- **Sound attenuation from external noise**

Again, off-site fabrication should help in achieving the required airtightness level for Passivhaus.

Window U-value less than 0.8W/m^{2}K

The triple glazed windows reduce unwanted cold down draughts by maintaining a minimum internal surface temperature of 17˚C, which is standard for Passivhaus and should be included as standard within the system. However, design decisions, such as concentrating window openings on the south facing elevation, and using appropriate shading, will help to reduce heat losses and manage solar gain.

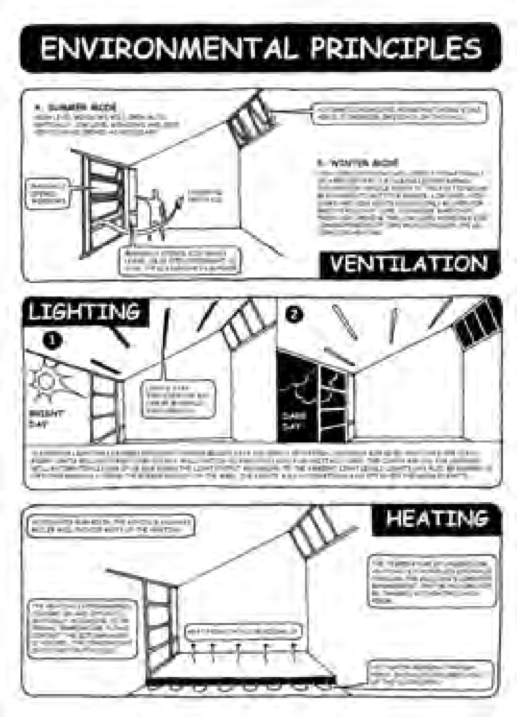
Fresh air ventilation 30m^3/person/hour

The system should also include an efficient controlled ventilation and heat recovery system to ensure optimum fresh air while managing heat recovery from outgoing air. This should maintain the optimum internal temperature with minimal heating and cooling equipment. However, the location of the unit and the design/ layout of the ducting will still affect the efficiency of the system.

The whole-building system approach

Overall, a whole-building system approach can assist with meeting Passivhaus requirements, particularly as the pre-fabricated components should have good performance characteristics and their use can reduce construction time, resulting in lower labour costs, and minimise on-site delays due to adverse weather conditions.

However, whole-building systems do not remove the need for effective design input, as outlined above. Orientation, services, design and other factors will all have a significant effect on the cost, efficiency and successful delivery of a project using a whole-building system.



LEFT: User guide cartoon sheet. Photo: Architype

Advantages

- A whole-building system can remove some of the complexities of ensuring that different materials and components can be combined to achieve Passivhaus requirements
- Prefabricated components can speed up construction time, resulting in lower labour costs
- Construction programme is less affected by bad weather
- The mechanisation used in construction increases conformity to the Passivhaus standard
- Materials are protected from exposure to the elements during construction
- Quality control and factory airtight sealing ensures better quality control

Disadvantages

- The system(s) may not work for all projects and design choices
- Effective design decisions are still required
- Space is required to transport manufactured modules or components to their site.
- Affordability may be an issue, particularly for smaller projects; increased production volumes on larger projects should offer greater affordability.

do

- **consider the orientation of the building early in the design as this will affect the fabric performance**
- **keep the form of the house as simple as possible which will reduce cost**

don't

- **design the house without using PHPP to model the energy flows**
- **over glaze the house so requiring expensive external mechanical shading devices**
- **always check if there are transport and access issues for delivering manufactured homes or modules to their intended site**

7 Construction and quality assurance

Mark Siddall

Summary

Training of site operatives, undertaking detailed site inspections, provision of robust feedback and the inclusion of a dedicated, on site quality assurance champion are all constituent parts of a successful delivery process. This chapter outlines those areas that require specific attention.

Introduction

With a sound design already in place, exemplary standards of on-site quality assurance are required in order for buildings to perform appropriately. This means diligence and excellent standards of craftsmanship must be employed at all times. For a project to be completed successfully, with minimised costly rework and remediation, experience suggests that there is a learning curve that needs to be addressed. This learning curve is not confined to the site office; it affects all trades on site.

Key stage design reviews

Structured reviews that interrogate a design are hugely beneficial, particularly for less experienced project teams. These reviews analyse each and every aspect of the design and the construction. Key characteristics:

- **They are not simply 'compliance reviews' – they dig into the details and examine the buildability, sequencing and construction programme.**
- **Their purpose is to identify and expose risks that could impact upon project delivery.**
- **They allow the project team the opportunity to formulate strategies that resolve the risks in an open and collaborative fashion.**

Training of site operatives (tool box talks)

On some building sites, traditional attitudes can be entrenched and effort must be made to bring all site operatives onboard. Each trade, from foundations to roof, has a part to play in the successful completion of a project. One of the best techniques is to hold a series of tool box talks that all site personnel are required to attend. New or replacement personnel should also receive an induction. Typically these tool box talks examine each detail, the sequence in which it will be constructed, the technologies that will be used when forming the

An Airtightness Team, comprising two Airtightness Champions, two Sealing Operatives also including the Site Manager, on the Erneley Close project. Photo: Paul Jennings

Good practice example

PHPP calculations suggested that the design had the potential to satisfy the Passivhaus Standard. The challenge lay in the actual implementation of the delivery process.

A series of Key Stage Design Reviews, training of the dedicated, on site Quality Assurance Champion, tool box talks and site inspections and Feedback underpinned the successful completion of the Certified Passivhaus homes at St. Mary's, Oldham. The result of these processes resulted in buildable details and simplified construction processes.

Site manager Anthony Kavanagh says:

'Compared to the Code 6 homes that are also on site I would prefer to build to the Passivhaus standard. The construction details that we have developed with Mark are proving to be far more practical and easier to build.'

A dedicated, on-site Quality Assurance Champion

The role of a dedicated, on-site Quality Assurance Champion is to make sure that the building satisfies its airtightness target. The role is to also help ensure that the correct insulation system is installed properly. This means ensuring that:

- the interface between insulation products has a good butt joint.
- the insulation is encapsulated between the air barrier and the wind barrier.
- the wind barrier system is completed in accordance with the design intent.

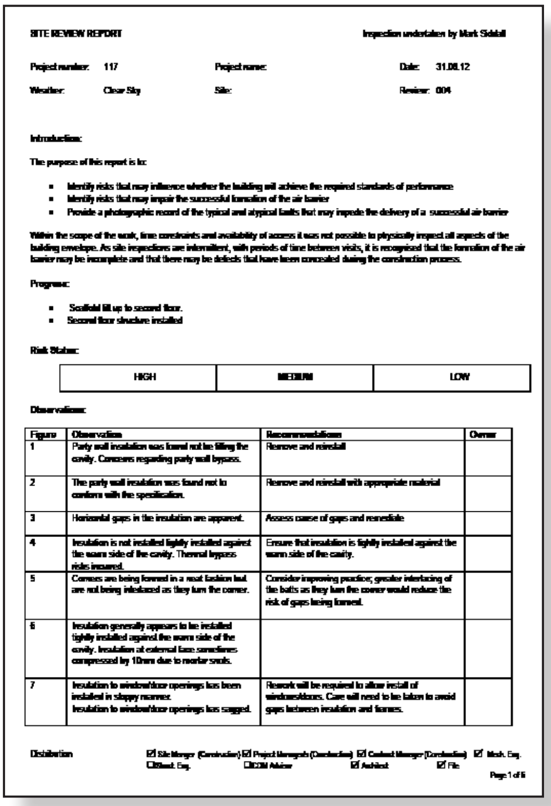
Their role is also to:

- Organise and arrange pressure tests.
- Arrange for timely tool box talks for all trades.
- Review the buildability of the air barrier, wind barrier and insulation systems – this means reviewing the sequencing of the build process and considering where challenges may arise before they become an obstacle.
- Undertake day to day site inspections of the work and instruct remediation as required.
- Ensure that only the specified materials are used in the construction i.e. avoid ad hoc substitutes, without prior consultation and agreement with the designer.

detail, and trades that will impact upon the successful completion of the detail. An atmosphere of collaboration helps these talks to work best and allows any sceptics to voice their concerns. Inviting sceptics to speak up is vital because:

Detailed site reports that support a useful, practical and fully functional feedback loop are invaluable. Discussing the contents of the reports with site managers, rather than simply handing over the document, is critical to establishing this feedback loop. The key thing here is the fact that, compared to standard practice, a closer working relationship is required for Passivhaus projects.

Site inspections may be made by the design team on a periodic basis. For this reason the site reports that they produce are only a snapshot in time. The best site reports also record the lessons learned from the site visit so that they may be fed forward to subsequent phases of the project and for future projects.



SITE REVIEW REPORT — Inspection undertaken by Mark Siddall

Project number: 117 | Project name: | Date: 31.08.12

Weather: Clear Sky | Site: | Review: 004

Introduction:

The purpose of this report is to:

- Identify risks that may influence whether the building will achieve the required standards of performance
- Identify risks that may impair the successful formation of the air barrier
- Provide a photographic record of the typical and atypical faults that may impede the delivery of a successful air barrier

Within the scope of the work, time constraints and availability of access it was not possible to physically inspect all aspects of the building envelope. As site inspections are intermittent, with periods of time between visits, it is recognised that the formation of the air barrier may be incomplete and that there may be defects that have been concealed during the construction process.

Progress:

- Scaffold lift up to second floor.
- Second floor structure installed

Risk Status:

HIGH	MEDIUM	LOW

Observations:

Figure	Observation	Recommendations	Owner
1	Party wall insulation was found not be filling the cavity. Concerns regarding party wall bypass.	Remove and reinstall	
2	The party wall insulation was found not to conform with the specification.	Remove and reinstall with appropriate material	
3	Horizontal gaps in the insulation are apparent.	Assess cause of gaps and remediate	
4	Insulation is not installed tightly installed against the warm side of the cavity. Thermal bypass risks incurred.	Ensure that insulation is tightly installed against the warm side of the cavity.	
5	Corners are being formed in a neat fashion but are not being interlaced as they turn the corner.	Consider improving practice; greater interlacing of the batts as they turn the corner would reduce the risk of gaps being formed.	
6	Insulation generally appears to be installed tightly installed against the warm side of the cavity. Insulation at external face sometimes compressed by 10mm due to mortar snots.		
7	Insulation to window/door openings has been installed in sloppy manner. Insulation to window/door openings has sagged.	Rework will be required to allow install of windows/doors. Care will need to be taken to avoid gaps between insulation and frames.	

Distribution ☑ Site Manager (Construction) ☑ Project Manager(s) (Construction) ☑ Contract Manager (Construction) ☑ Mech. Eng. ☐ Struct. Eng. ☐ CDM Advisor ☑ Architect ☑ File

Page 1 of 6

Example of Site Report used by Mark Sidall for a Passivhaus development

don't

- hope for the best
- fail to plan for success
- rely upon standard industry practice when planning construction programmes
- forget to undertake site inspections and feedback

do

- allow time for planning (it will pay back in the future)
- undertake Key Stage Design reviews
- train site operatives
- ensure that there is a dedicated, on-site Quality Assurance Champion
- remediate mistakes ASAP (when you still have the chance)

Case Study Wilkinson Primary School

Wilkinson Primary School in Wolverhampton is the third collaborative Passivhaus school project by contractors Thomas Vale and architects Architype.

Building on the lessons learnt during the design and construction of Bushbury Hill and Oakmeadow Primary Schools, the project team sought to deliver their third Passivhaus school on an even tighter budget.

The project team attended regular design review meetings to check progress and structured reviews that interrogate a design are hugely beneficial, particularly for less experienced project teams. These reviews analyse each and every aspect of the design and the construction.

ABOVE: Having learnt the ropes on two earlier schools, most passivhaus related snagging was carried out by the Architects (Lee Fordham pictured) with minimal input from the Passivhaus consultants Elemental Solutions. LEFT: Checking for air leaks with a thermal imaging camera. Photos: Nick Grant

BELOW: Wilkinson Primary School, Photo: Architype

Core Components of a Passivhaus Project Management Checklist

By failing to recognise the boundary between a certification process and the design and construction process individual projects are at risk and may encounter difficulties. In part this may be because the industry has become used to certification systems that are less rigorous and have permitted this gap to go unobserved.

Listed below are the major components that are included on a Passivhaus Project Management checklist. Each component, and it's constituent sub-components, should be coordinated with relevant BS EN Standards. When a building is to be certified it is vital that this checklist is developed and agreed with an approved Passivhaus Certifier.

Key stages where photographic evidence of the construction should be gathered by appropriate members of the design and construction team. On a project specific basis the Passivhaus consultant should assist with agreeing the regime for compiling evidence.

Training/ toolbox talks (pre-start)

- Site storage
- Workmanship
- Activities to be undertaken
- Sequencing of activities

Ductwork protected from site debris during storage.

Insulation installation - materials & workmanship

- Walls, Roof, Floor, Windows
- Junctions
- Services

Check construction tollerances. Insulation is encapsulated tightly between internal and external leaf to avoid thermal bypass.

Windtightness - materials & workmanship

- Primary wind barrier system
- Window Installation
- Service penetrations

Airtightness - materials & workmanship

- Primary air barrier system
- Window Installation
- Service penetrations

Air barrier installed in a manner that allows easy inspection and remediation during construction.

Services - materials & workmanship

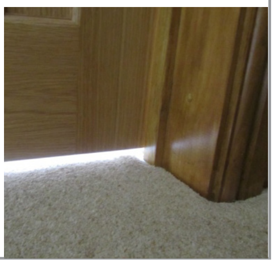
- MVHR unit installation
- MVHR ductwork & silencers
- DHW
- Pipes and plumbing
- Heat sources
- Controls

Ductwork protected from site debris during instalation.

Builders Work

- Joinery (door over/undercuts etc)

Air transfer provision is checked against design drawings and specification.



Practical completion (summary report)

Photos: Mark Siddall

8 Certification and quality assurance

Kym Mead

Summary

Passivhaus buildings maintain comfortable indoor temperatures all year round with extremely low energy demands. This is achieved by careful design, robust detailing of the building fabric and services, and effective quality control of the construction process. Certification is essentially the formal assessment and approval of the quality of the project.

Introduction

Essentially Passivhaus certification is a quality control process that ensures that the building will perform as designed. It is advisable that a building certifier or experienced CEPH designer/consultant has early input into the design pre planning stage as they will be able to advise on the insulation and glazing choices in relation to the orientation and massing of the design. The other crucial stage is a pre construction check, where confidence can be given that the design will meet the Passivhaus target, ideally before work on site starts.

Passivhaus certification

The Passivhaus Standard is voluntary and based purely on building physics which applies to both domestic and non-domestic buidings. The criteria for Passivhaus certifcation are performance based, instead of individually specified construction or technical details. Certification requires that overall planning is carried out with a calculated energy assesment within the Passive House Planning Package (PHPP), plus elaboration of the details and supporting documentation on components and services. This ensures that the planned building will actually perform as designed.

Careful planning

Certification is intended to ensure a good quality of work. Airtightness, thermal bridges, the quality of the windows and their installation, the ventilation system and other building services will all be checked as part of the project. The main factor in successfully achieving certification is planning, as only careful and considered planning will ensure you complete all the required factors to achieve the Passivhaus standard.

MEAD: Energy & Architectural Design Ltd
3 Harvey Road
London
N8 9PD

Authorised by:
Passive House Institute
Dr. Wolfgang Feist
Rheinstr. 44/46
D-64283 Darmstadt

Certificate

MEAD: Energy & Architectural Design Ltd awards the seal "Certified Passive House" to the following building

Caister, Charles Close, Caister-on-sea, Great Yarmouth, UK

Client: **Great Yarmouth Development Company**
Hall Plain, Great Yarmouth, NR30 2QF

Architect: **NPS Property Consultants Ltd**
16 Central Avenue, St Andrews Business Park, Norwich

Mechanical Systems: **Total Home Environment**
Swallow House, Cotswold Business Park, London Road,GL56 0JQ

This building was designed to meet Passive House criteria as defined by the Passive House Institute. With appropriate on-site implementation, this building will have the following characteristics:

- Excellent thermal insulation and optimised connection details with respect to building physics. The heating demand or heating load will be limited to
  15 kWh per m^2 of living area and year or a heating load of 10 W/m^2, respectively
- When outdoor temperatures are high, thermal comfort can be ensured with passive solutions or with minimal energy demand for cooling and dehumidification according to the location-specific Passive House requirements.
- A highly airtight building envelope, which eliminates draughts and reduces the heating energy demand: The air change rate through the envelope at a 50 Pascal pressure difference, as verified in accordance with ISO 9972, is less than
  0.6 air changes per hour with respect to the building's volume
- A controlled ventilation system with high quality filters, highly efficient heat recovery and low electricity consumption, ensuring excellent indoor air quality with low energy consumption
- A total primary energy demand for heating, domestic hot water, ventilation and all other electric appliances during normal use of less than
  120 kWh per m^2 of living area and year

This certificate is to be used only in combination with the associated certification documents, which describe the exact characteristics of the building.

Passive Houses offer high comfort throughout the year and can be heated or cooled with little effort, for example, by heating/cooling the supply air. Even in times of cold outdoor temperatures the building envelope of a Passive House is evenly warm on the inside and the internal surface temperatures hardly differ from indoor air temperatures. Due to the highly airtight envelope, draughts are eliminated during normal use. The ventilation system constantly provides fresh air of excellent quality. Energy costs for ensuring excellent thermal comfort in a Passive House are very low. Thanks to this, Passive Houses offer security against energy scarcity and future rises in energy prices. Moreover, the climate impact of Passive Houses is low as they reduce energy use, thereby resulting in the emission of comparatively low levels of carbon dioxide (CO_2) and air pollutants.

issued: 16.06.2014

Kym Mead,
MEAD: Energy & Architectural Design Ltd,

Certificate-ID: **9030_MEAD_PH_20140623_KM**

Quality Assurance Certificate awarded on successful completion of a Passivhaus development

The QA certificate

After the building has successfully achieved the required airtightness level and the commissioning of the building services has been completed, the project is assessed and checked as part of the final quality assurance check, or Certification. Upon successfully achieving all criteria the building certifier will issue the 'Passivhaus Quality Assurance Certificate' to the design team or client.

Checklists

All accredited Passivhaus certifiers use checklists for their quality assurance, which are normally provided on their appointment to the project. These checklists should be referenced during the design stages with information collated as the project develops; this will save time when checks need to be made and signed off by the certifier.

The benefits of certifying a Passivhaus for the designer and building owner

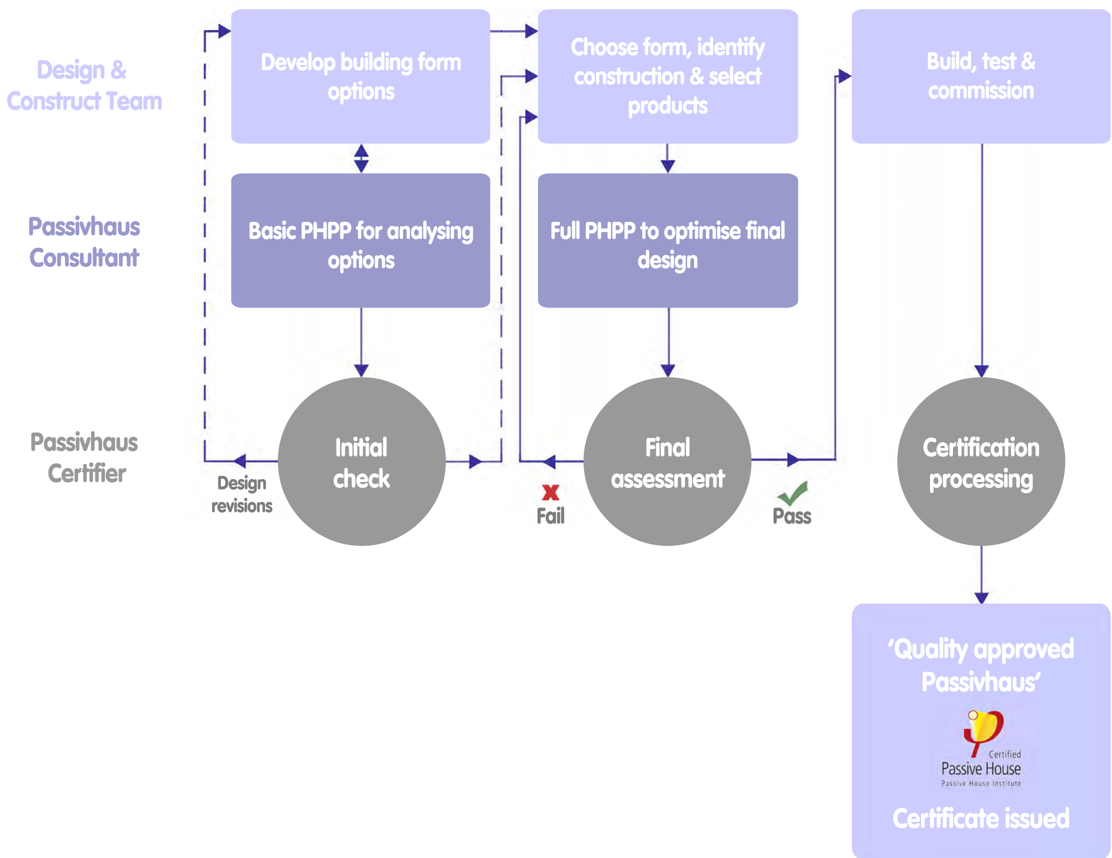
- The certification of a Passivhaus through an accredited building certifer offers quality assurance.
- The experience of bulding certifiers can benefit designers and architects throught the design and construction process.
- In the process of certification, the designer receives valuable hints about how quality can be improved, and how solutions can be simplified and implemented in a better and more cost-effective way.
- The support provided by an experienced Passivhaus certifier can result in a more economical building.

do

- engage with a Passivhaus Certifier at the earliest opportunity
- model your design in PHPP at the early design stages
- make sure you are using the correct climate data within PHPP

don't

- assume that a building specification from a previous development will suit all future Passivhaus buildings
- leave the collation of information to the last minute as this could cause delays in the building being certified



Example of the certification process.

9 Handover, maintenance and comfort

Chris Parsons

Summary

It is sometimes thought one drawback of the Passivhaus standard is that it requires occupants to change their behaviour, yet a properly designed Passivhaus should not require any significant behavioural change.

Passivhaus comes in all varieties; not just domestic dwellings, but schools, hotels, hospitals can all be delivered to the standard. The design should only include components and controls that are appropriate for the skills and understanding of the occupants.

Introduction

Each Passivhaus is bespoke in the sense that there is no standard typology, meaning the handover process and the maintenance regime needs to be tailored every time to suit different heating, ventilation and cooling methods, different equipment and component demands, and different occupant types. As always, understanding is the key. For the occupant, a clear understanding of the controls and techniques available to them will ensure they can achieve a comfortable environment with very low energy demands. For those responsible for maintenance, an understanding of the sensitivities and contribution of components to the overall performance will ensure the comfort and energy qualities are delivered.

Advance information

Advance information in the form of a general explanation of the Passivhaus standard and methodology, and how it applies to the specific project can be a helpful start.

'Quick start'

Identify any maintenance items to be carried out by the occupier, and provide clear and simple instructions for doing so. These can be supplemented by stickers or laminated posters affixed to the equipment if helpful.

Provide a very simple 'quick start' guide to the various controls and techniques, checked and proof read by a non-technical person, ideally someone fluent in the occupier's language. It should contain a short simple overview followed by a number of simple headings such as 'what to do if my home is cold' etc. The advice should be limited under each section to no more than a couple of paragraphs. If it needs more than that, your Passivhaus is not passive enough! Including photographs or graphics of the controls being discussed, with simple descriptions of each function, will be helpful.

Also identify who to call when faults or more complex maintenance tasks require action, and if necessary, include a script to use. Complications often arise with inexperienced call centres who may not know what a Passivhaus is or what MVHR stands for.

Wall stickers at Gentoo's Passivhaus Racecourse Estate. Photo Alan Clarke

Other information

Consider the provision of stickers or laminated graphic instructions affixed to plant where maintenance is to be carried out by occupants, or untrained persons. More technical or complex documents should be included as appendices within the overall building manual or log book.

Consider making a short yet specific 'how to' video of each topic for posting on a video sharing website (maybe with a DVD copy for the occupants). These can be accessed on tablets, smart phones and computers and the internet is often the first reference point for today's generations.

don't

- over complicate user guides
- try to familiarise on 'move in' day
- frighten occupants with complicated or technical explanations
- leave the maintenance team in the dark

do

- provide advance information. The earlier the journey starts, the sooner it finishes
- provide a very simple 'quick start' guide, stickers or posters where appropriate
- consider accessible video guides
- set the building up to function prior to 'move in' day
- familiarise occupants through 'hands on' experiences
- re-familiarise at change of season
- involve maintenance teams in the design
- ensure fault response teams are well informed

Door hangers at Gentoo's Passivhaus Racecourse Estate Photo: Alan Clarke

Handover

Set everything up to be working on 'move in' day. This allows occupiers to concentrate on the actual move, without having the added complication of learning new controls and techniques on the day. The 'quick start' guide should form a part of the general documentation which should be handed over on move in day.

Arrange a familiarisation session for a week or two after moving in, with as many occupants as possible. Consider who should lead the session. It is important not to overwhelm or frighten the occupants with hoards of technical experts. In a relaxed atmosphere, work through the 'quick start' guide (perhaps using a checklist) and explain each of the main functions. Involve occupants in hands on experience, and avoid the temptation to demonstrate. Learning by 'doing' is far more effective and confidence building. Questions often occur after the session so provide a further point of contact.

Repeating a similar familiarisation session at the following change to winter/summer provides an opportunity to catch up with how the users have coped so far as well as to go over how users might control for cooling instead of heating, for example.

Case Study Burnham Overy Staithe

Following the delivery of a number of Passivhaus schemes, Hastoe Housing Association have continually reviewed their handover procedure to incorporate a number of revisions, incorporating lessons from each.

Recognising that tenants would have no special knowledge of the Passivhaus methodology, the handover procedure adopted at Burnham Overy Staithe began during design stage with the preparation of a plain English guide for residents. An 8-page A5 size illustrated booklet which answers questions such as 'What should I do if my house is cold?' offers occupiers simple and easy-to-follow instructions for all the major controls.

Tenant familiarisation sessions took place two weeks after occupation with a 'hands on' try out of each control. Occupiers were encouraged to operate the controls themselves rather than have them demonstrated, to ensure they were comfortable in their use. Parsons + Whittley, the architects, produced a checklist to make sure nothing was forgotten and ran through an explanation and discussion of the questions raised in the handbook. Contact details were left should occupants have further questions.

RIGHT: The handover checklist developed for Burnham Overy Staithe by Parsons +Whittley Architects and Hastoe Housing Association.

		Done
1	Welcome and Introduction to Passivhaus	
	Insulation	
	Windows	
	Air tightness – reduced draughts	
	Heat from occupation and solar gain	
	Heat Recovery	
2	Heating System	
	Strategy (if house is cold/warm)	
	Windows closed	
	Controls	
3	Domestic Hot Water	
	Controls	
4	Cooling	
	Heating Off	
	Windows – purging strategy	
5	Ventilation	
	MVHR – principles	
	Controls	
	Fan Speeds	
	Filter Change	
6	Air Leakage	
	Holes!	
7	Fuels	
	LPG – Changeover arrangements	
	Electricity – Smart Meters	
8	Other	

The Passivhaus Trust would like to thank the sponsors of How to Build a Passivhaus: Rules of Thumb for making this publication possible, including the commissioning of independent authors

Publication sponsors

Chapter sponsors

"I read that the construction industry had experimented with adding insulation to new buildings and that energy consumption had failed to reduce. This offended me – it was counter to the basic laws of physics…
So I made it my mission to find out what (they were doing wrong) and to establish what was needed to do it right."

Professor Wolfgang Feist, Founder,
Passivhaus Institut, Germany

Useful links

The Passivhaus Trust
www.passivhaustrust.org.uk
The UK Passive House organisation.

The Passivhaus Institut (PHI)
www.passiv.de/07_eng/index_e.html
Founded in 1996 as an independent research institute under the leadership of Dr. Wolfgang Feist. The PHI developed and promoted the Passivhaus concept in Germany and worldwide.

The International Passive House Association (iPHA)
www.passivehouse-international.org
The International network for Passivhaus knowledge, working to promote Passivhaus worldwide.

Passipedia
www.passipedia.passiv.de/passipedia_en
iPHA's wiki-based Passivhaus resource featuring in-depth research and years of accumulated knowledge.

The iPHA forum
www.forum.passivehouse-international.org
A dynamic platform for the direct exchange of ideas on all things Passivhaus amongst iPHA members.

Cepheus
www.cepheus.de
A project within the THERMIE Programme of the European commission. Measurement and evaluation of 250 houses to Passivhaus standards in five European countries.

UK Passivhaus buildings database
www.passivhausbuildings.org.uk
Details of many new and retrofit UK buildings certified to Passivhaus standards.

Passnet
www.pass-net.net
Project to spread knowledge of the Passivhaus standard within Europe, through open days and a buildings database.

For more information on membership, training or events visit The Passivhaus Trust website:
www.passivhaustrust.org.uk

How to build a Passivhaus
Rules of Thumb

If you'd like to learn more about the Passivhaus Standard, The Passivhaus Trust offers different level membership packages and runs a series of annual training courses and events.

Passivhaus Trust membership

Helping to promote the Passivhaus standard in the UK, influence policy-makers, developers, clients and other key players, network with leading Passivhaus experts, practitioners and academics, access the latest technical information and experience relating to Passivhaus in the UK

Passivhaus Trust MEMBER

Passivhaus Trust PATRON

Training courses

The Trust, through its members, deliver training courses for both entry level and advanced Passivhaus practitioners with in-depth training materials and exercises.

Passivhaus Trust Tutorial

Passivhaus Trust Expert Panel

Passivhaus Trust Masterclass

Competitions and events

The aim of the UK Passivhaus Awards and Open Haus is to promote the Passivhaus Standard in the UK, to encourage and drive enthusiasm for the Passivhaus standard whilst showcasing the UKs pioneering projects.

OPEN HAUS

Passivhaus Trust Awards 2015

ukpassivhaus conference2015

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£5 plus VAT members

£10 plus VAT non-members

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