Passive House Technical Overview: Part 2

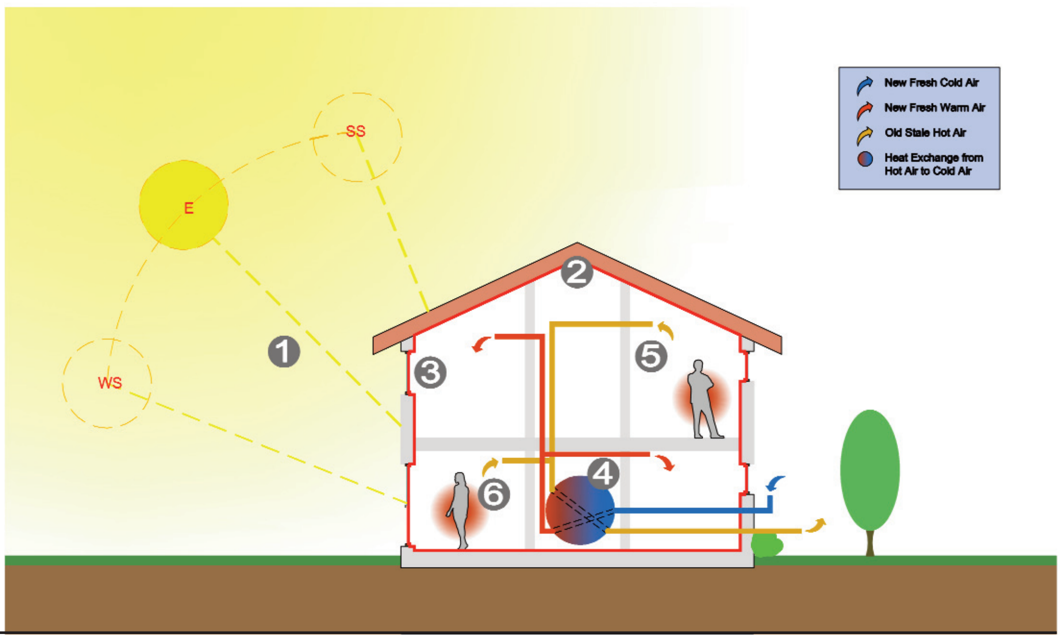
Certified Passive House Designer Steff Bell Bsc (Hons) ACIAT explains the passive house concept in more detail in the second and final part of his article on the subject.

In the first part of this article, I looked at the concept of the Passive House standard and discussed what made a Passive House building different to a standard building. Having set out important information such as the certification process and the methods of calculation required for compliance with the standard, we can now have a closer look at the technical aspects of Passive House design and outline the main criteria and sub-criteria which aid designers in achieving a certified Passive House.

As with any project the site and surrounding area will play a major role in what is ultimately possible. However, there are a number of constant factors that can improve a building's performance with regard to becoming a Passive House. Provided a design meets the performance criteria, and is modelled in the PHPP, the designer has a high degree of flexibility in designing a Passive House as they wish. It is worth noting though that deviation from the following additional design considerations can result in an increase in capital costs due to additional compensation for avoidable and unnecessary heat losses. (see picture one: Passive House Diagram illustrating the criteria.)

Orientation and Form

A compact building form, with minimum surface to volume ratios, ensures a reduction in thermal bridging and heat loss, whilst a south facing orientation with large areas of glazing (25-30%) maximises solar gains and provides a passive heat source for



Right: Picture one- Passive House diagram showing the main criteria as required in Passive House design

Right: Picture four – Internal view of pre-fab wall panels with joints and insulation holes taped and sealed for air-tightness

Right: Picture two – Passive House in Steingaden Germany (Herz & Lang project) North-East facades, minimal windows to the North.

Right: Picture five – Areas of a house being tested for air-tightness

Right: Picture three – Super insulated walls in Munich Germany (Herz & Lang project)

Right: Picture six – Pressure test being conducted in a Passive House project

the building (see picture two above). Natural shading methods such as roof overhangs, free standing balconies and deep window recesses should be considered in the design to avoid overheating in the summer. Other forms of shading, popular in both Germany and Austria, include concealed roller shutters and exposed manual shutters.

Preventing Heat Loss: Building Fabric

Super Insulation

The building fabric is one of the most important factors of a successful Passive House construction. The insulation surrounding a Passive House building should be applied without gaps, creating a continuous thermal envelope around the entire heated area of the building, similar to a giant sleeping bag. These super insulated wall, roof and floor elements play a large role in reducing the amount of heat loss, making it possible to heat the building without a conventional heating system. These components have a recommended U-value of less than 0.15 W/m²K (sub-criteria) and can vary in size with typical Passive House wall and roof constructions being up to 350-500mm thick, with typically 300mm Insulation or more (see picture three above).

Air-tightness

In addition to the super insulation, the building envelope is surrounded by one continuous airtight layer with all components and connections fitted in an airtight manner. Air-tightness tapes and seals are applied around all areas where components meet, with special attention paid to the installation of electrical and mechanical services. Air-tightness in a Passive House is verified by conducting a pressure test (blowerdoor test) to measure the amount of air changes the building experiences within one hour. In order to achieve certification, the building's pressure test result (measured at 50 Pascal difference between inside and outside) must not exceed more than 0.6 ac/h^{-1}. If the building's air changes per hour are more than 0.6 ac/h^{-1} then too much heat will be lost through leakages and the reduced energy targets of less than 15kWh/(m²a) will not be reachable (see picture four, five, six).

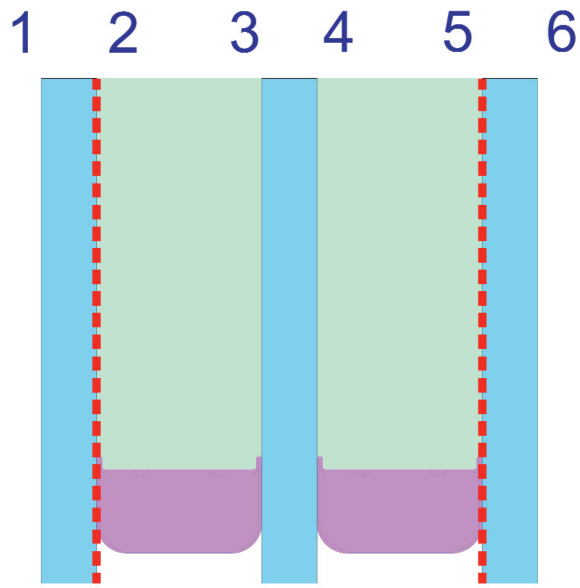
Thermal bridge free design

The third way in which heat loss can be reduced through the building fabric is to eliminate the thermal bridging effect (also known as cold bridging). Windows and door frames are insulated over, and the building is detailed in such a way that areas where solid components meet are reduced, or eliminated, so that heat does not have a clear path from the inside of the building to the outside. Thermal bridge calculations are conducted (commonly using the therm or heat programmes) in order to accurately detect and eliminate any area that may create a thermal bridge. Thermal bridging within a Passive House building is recommended to be below 0.01 W/(m²K) (sub-criteria) as calculated on an external dimensions basis.

Passive House Windows

The windows in a Passive House are required to have a much lower U-value than standard windows so as to prevent excessive heat loss. The recommended Passive House window U-value is no higher than 0.8 W/(m²K) (sub-criteria) and an installed U-value of no higher than 0.85 W/(m²K) (sub-criteria). These values are

Below: Picture seven – Passive house window section diagram with the low-e coatings applied to glazing surfaces two and five



Right: Picture nine – MVHR unit in Dunoon Scotland (Scottish Passive House Centre project)

achieved by a combination of triple glazing with two low-e coatings (typically on glazing surfaces two and five and filled with argon or krypton gas), warm edge spacers and frames with increased insulation levels (sub-criteria). (see picture seven.)

Whilst this reduces heat loss through the windows, this element of the Passive House building has a dual purpose and must also allow a beneficial amount of solar gains to enter the dwelling. With this in mind the window glazing must have a minimum solar energy transmittance factor of 50% (G-factor = 0.5, sub-criteria) with 62% (G-factor 0.62) being the highest currently achievable with Passive House windows.

The human body is particularly sensitive to temperature differences within a room, in the form of radiant temperature asymmetry and temperature stratification. Radiant temperature asymmetry describes a situation where objects simultaneously radiate different temperatures towards our bodies; in this situation a temperature difference of 4K or above will cause discomfort. Temperature stratification describes a situation where there is a temperature difference between heights of 1.1 to 0.1m within a room, in this case a temperature difference of 2K or above is enough to cause the feeling of discomfort.

An advantage of such low heat loss values through the Passive House window components is that their internal surface temperatures will be higher than 17°C (sub-criteria), even during the evenings in winter. The result of this is a dramatic improvement in a building's thermal comfort, especially when sitting next to the windows, as the improved internal temperature will eliminate cold drafts due to temperature stratification, and discomfort due to a radiant temperature asymmetry within a room.

The ventilation system provides a steady stream of fresh warm air to the building

Maximising Heat Gains: Mechanical Ventilation with Heat Recovery (MVHR)

All rooms within the thermal envelope (inside the continuous air-tight layer) are ventilated via the use of a mechanical ventilation system with heat recovery. The requirement for performance of an MVHR system, within a Passive House, is a minimum heat recovery efficiency of 75%, with an energy consumption of no more than 45Wh/(m^3) (sub-criteria).

The ventilation system provides a steady stream of fresh warm air to the building which is an absolutely vital requirement as the building envelope renders the building almost completely airtight. The average air change rate per person in a Passive House is 20-30 $m^3 h^{-1}$ (sub-criteria) with higher air change rates in rooms with excess moisture, or odours such as kitchens and bathrooms.

The air flow rate of the ventilation system must be balanced which is most commonly achieved by dividing the house into supply air rooms (such as bedrooms and living/dining rooms) where fresh air is provided; overflow areas (such as hallways and stairwells/landings) where the air is drawn across a space; and exhaust air rooms (such as kitchen, bathrooms and laundry rooms) where the stale air leaves the building. (see picture eight)

The heat recovery part of the ventilation system recycles the heat from the used stale air and uses this to pre-heat the fresh clean air being pumped in to the building (with a minimum efficiency of 75%). This means that in order to reach the Passive House internal design temperature of 20ºC (sub-criteria) the building only requires an additional 4-5˚C from space heating, as the other 15-16˚C will be recovered from the exhaust air, and channelled back into the building through the supply air. (see picture nine).

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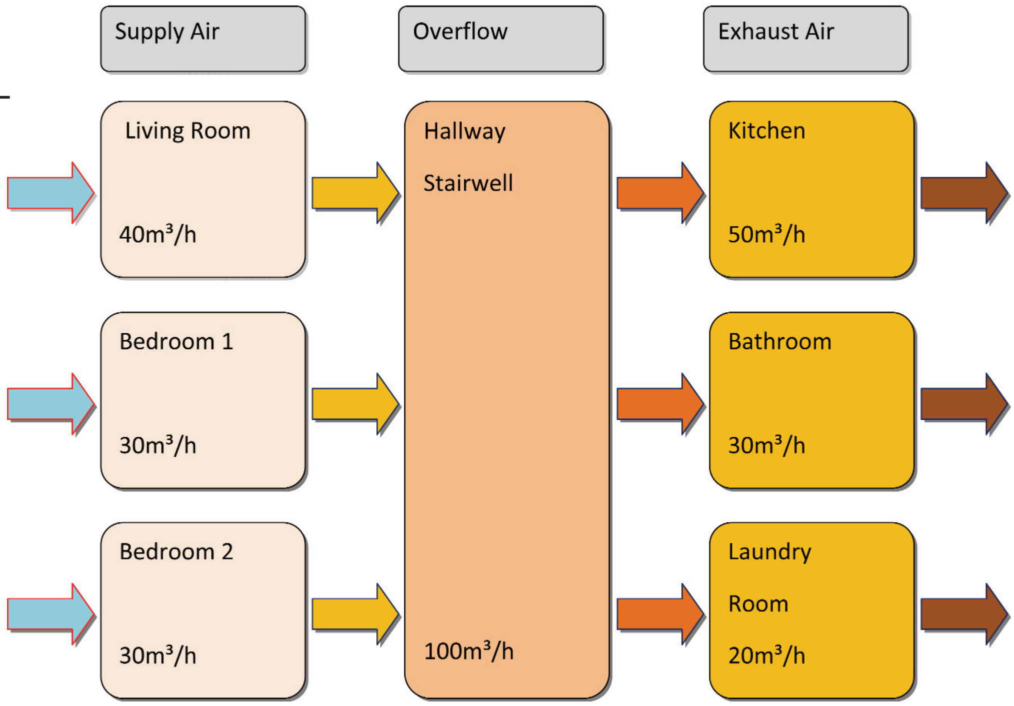

Right: Picture eight – Ventilation balancing table for an MVHR system in a Passive House

Space Heating

An efficient MVHR system ensures that the buildings space heating requirements are reduced to such a degree that conventional heating systems are no longer required. In addition to the 15-16˚C the building receives from the MVHR unit, solar gains obtained from the large South facing glazing and internal heat gains, such as body heat, (an average person can emit 100W of heat energy) lighting and household appliances will easily provide the remaining 4-5˚C required to achieve the design temperature of 20˚C. In some months (mainly summer and autumn) the house will reach this temperature very quickly and must rely on external shading and shock ventilation to prevent the house from over heating by more than 10% (sub-criteria) at which point it would become very uncomfortable. A useful technique for avoiding overheating in the summer is a summer bypass function within the MVHR unit. This allows the system to prevent the heat recovery function therefore reducing the amount of heat that is brought into the building without reducing the amount of fresh air.

Whilst generally, it is the case that a conventional heating system is not required in a Passive House, additional heating may be required during the very coldest days of winter, in order to help the house comfortably reach the 20˚C design temperature. This additional heat can be provided by a range of different methods, the most common of which is via a supply air post heater, situated after the heat exchange unit, at the beginning of the supply air duct, inside the buildings thermal envelope. This source of heat can take the form of electrical heating coils, a small heat pump, solar thermal or even the more conventional oil burner or natural gas. For the purposes of reducing smells from singed dust that may be in the ducts, despite the numerous filters, the supply air temperature must not exceed 52˚C (sub-criteria).

Lighting and Appliances

Low energy lighting and efficient household appliances are most commonly used within Passive Houses in order to achieve the primary energy consumption criteria of less than 120 kWh/(m²a).

Conclusion

This concludes my introduction to the Passive House Standard and the criteria used in order to achieve a certified Passive House. As discussed in the first part of this article, the Passive House standard in the UK is growing in both popularity and reputation, with an estimated 20– 35 Passive House buildings in existence and a great deal more currently under construction or at the planning stage. The biggest driver for change in any field is the backing of industry professionals, which only comes with a greater understanding of the subject in question. I hope that this article has enabled people to further understand the potential the Passive House standard has to offer the UK and that this will encourage practices to learn more about the standard and to start using it for buildings in the future.

If anyone has any questions or would like to discuss further the possibilities of implementing the Passive House standard on future projects please fell free to contact me using the following details:

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Correction

In the previous part of this article (Issue 88) there were two errors in the labelling of pictures.
The image on page 14 required the label 'Scotland's Highland Housing Fair, HLM Architects'.
The image on page 15 was a Herz & Lang project.