Passivhaus Trust
The UK Passive House Organisation

Designing for Summer Comfort in the UK

October 2016
Revision 0.1

Contents

Acknowledgements

This paper was written by Mark Siddall & Nick Grant, with input from: Mike Roe, Kym Mead, Will South, Alan Clarke, Zeno Bastian, Dave Edwards and Kate de Selincourt

Introduction

The overheating of buildings is a growing concern in the UK. This document outlines common problems and a recommended approach to designing for summer comfort in the UK climate for domestic dwellings up to four storeys high; non-domestic buildings and multi-family dwellings are not discussed in detail, although most of the same principles apply. Examples include hot water distribution, lighting in circulation areas and other additional sources of unwanted heat as well as the control of ventilation and heating and possible thermal separation between units. This document complements the detailed guidance in the Passivhaus Trust booklet "How to Build a Passivhaus." Whilst it includes some details and examples it does not replace practical design guidance or the need to test each design to ensure it is fit for purpose.

Passivhaus buildings are known for delivering excellent winter comfort in the coldest of climates, with no draughts or condensation, and lower heating bills. The Passivhaus Standard also includes targets for summer comfort (including humidity) and the Passivhaus design software (PHPP) provides increasingly powerful tools to consider this.

Delivering summer comfort can be more of a challenge because, whilst there is always a heating system to control winter temperatures, there is typically no source of active cooling available in the summer. Other European countries with hotter summers than the UK manage to maintain comfortable temperatures in their low-energy buildings without active cooling, so it follows that active cooling should not be required in the UK.

Typically, in warm-hot climates, buildings have always had to be designed to cope with hot summer temperatures and the building's occupants have learned how to keep a building cool by the use of shading and night ventilation. Where this is not possible (e.g. in noisy environments) cooling will probably be specified. Although a warming climate is sometimes blamed for the increase in overheating, the real issue is the change in our buildings. The insulation we use to keep us warm in winter also retains heat from sun and internal gains in summer. If this heat gain is not removed, we become uncomfortable. Even more significantly, high performance glazing allows us to install more glass in our buildings without winter discomfort or high heating bills. However, the increased glazing considerably raises the risk of overheating.

Whilst it is now generally accepted that good low-energy design is more about the reduction of the heating demand than passive solar gains, Passivhaus buildings with a particularly poor form factor can end up with additional south glazing as the only practical way to achieve the 15kWh/m^2.yr annual heat demand target. This has been a particular problem with very small buildings though it has been largely addressed by improvements in the calculation methodology in PHPP 9 (Schnieders, 2015).

Future Climate scenarios

Whilst extreme weather events are predicted to become more frequent, they can happen at any time and in any year. For these reasons it makes sense to design buildings with plenty of leeway for coping with the heatwaves of today.

Future changes to the climate could eventually make night cooling and natural ventilation strategies ineffective. In this case, active cooling and possibly dehumidification will be required to ensure summer comfort.

Some academics have suggested that designing buildings to reduce energy use under current climate conditions will lock us in to over-insulated buildings that will be unsuitable for a warmer world. For buildings with active cooling, high levels of insulation, airtightness and low internal heat gains reduce the cooling load and allow simpler systems to be installed. However, excessive solar gain remains a concern and can lead to direct radiant discomfort even when air temperatures are within the comfort zone.

Designing for summer comfort

There are a number of UK standards and guidance notes which set overheating limits for dwellings and non-domestic buildings. Some standards specify maximum temperatures, durations of time and/or permitted frequencies (or hours) of exceedance.

Standard	Building Type	Peak Summer Temp.	Durations of Time	Permitted Exceedance
DfES BB87	Schools	28°C	Occupied hours/year	80 hours
Housing Health & Safety Rating System (HHSRS)	Dwellings	25°C	Occupied hours/year (inferred)	Unspecified.

Table 1a: DfES and HHSRS overheating standards

Standard	Building Type	Acceptable Range	PMV*	Max. Daily Temp. Summer	Duration of Time	Occupied Hours Exceeding θmax	Assessment of Daily Overheating Severity
CIBSE Guide A (section 1.5.3.2) based upon BS EN 15251 (Category II)	Dwelling	± 3 K	± 0.5	26°C	Occupied hours/year	< 3% when ΔT > 1K between May and Sept.	Weighted exceedance < 6
	Offices	± 3 K	± 0.5	26°C			
	Retail	± 3 K	± 0.5	25°C			
	Schools	± 3 K	± 0.5	25.5°C			
For more information on these standards refer to CIBSE Guide A. *Predicted mean vote.							

Table 1b: CIBSE overheating standards

Standard	Building Type	Calculated Peak Temperature	Evaluation
SAP* Appendix P (Table P2)	Dwellings	< 20.5°C ≥ 20.5°C & <22°C ≥ 22°C & <23.5°C ≥ 23.5°C	Not significant Slight Medium High
* It should be noted that the Standard Assessment Procedure (SAP) is a regulatory tool, not a design tool.			

Table 1c: SAP overheating standards

The Passivhaus Standard for Summer Comfort

The certification requirements for summer comfort are based on the assessment carried out in the Passivhaus Planning Package (PHPP). For apartments and non-domestic buildings, a dynamic model is usually recommended to demonstrate compliance.

The measure of summer comfort is defined by the percentage of hours in the year (total-hours) where temperatures rise above an established threshold of 25°C. For example, if the 25°C threshold is exceeded for 10% of the year then the indoor temperature would exceed 25°C for 876 hours (0.1 x 8760 hours). This limit establishes the threshold for summer comfort. Table 2 below depicts the summer comfort scale Passivhaus designers are recommended to use.

Hours >25°C	Hours/year	Assessment
> 15%	>1314	Catastrophic
10-15%	876-1314	Poor
5 – 10%	438-876	Acceptable
2 – 5%	175-438	Good
0 – 2%	0-175	Excellent
Maximum daily temperature swing according to PHPP 3K (to ensure reliable modelling)		

Table 2: summer comfort scale for Passivhaus buildings.

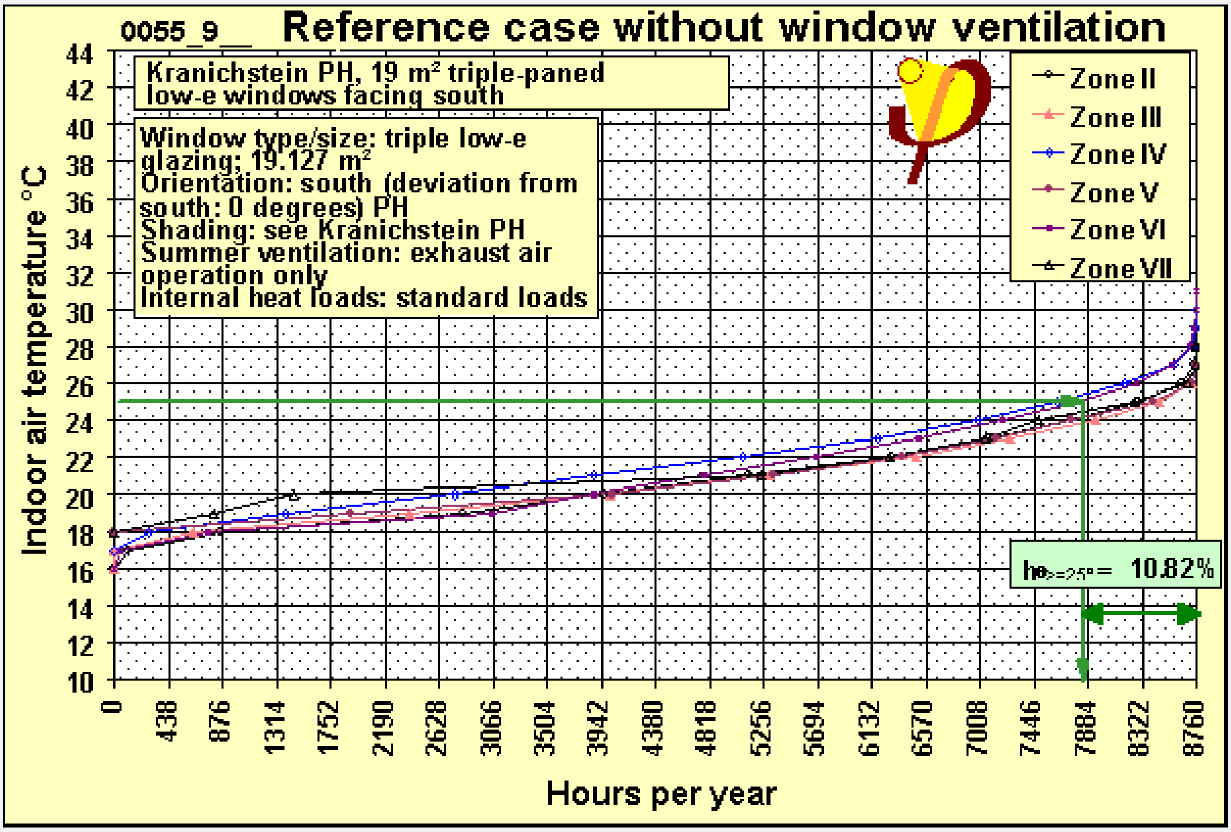
Overheating, to one extent or another, can be considered to occur when the indoor temperature is greater than 25°C for more than 876 hours per year. In practice buildings designed to remain below 25°C (according to PHPP) for 90-95% or more of the year are generally expected to be comfortable.

For the purposes of Passivhaus Certification, the summer comfort condition must be assessed using the PHPP as being 'Acceptable' or better. Less than 5% over 25°C is typically considered a suitable target and many designers aim for 0% hours.

PHPP also calculates the daily temperature swing in summer. A 3Kelvin swing is a limit for accurate estimate of overheating but is also a useful indicator that a building is likely to overheat due to excess glass compensated for by lots of ventilation. Whilst this is not criteria for certification it is a very useful indicator of summer performance. However, as with all models, and the standards mentioned above, the results are very sensitive to assumptions.

As observed in Table 1, other standards often refer to temperatures exceeded for a percentage of occupied-hours (rather than total-hours). This can be a source of confusion when attempting to compare standards.

The Foundry, 5 Baldwin Terrace, London, N1 7RU I 020 7740 3502 I www.passivhaustrust.org.uk I info@passivhaustrust.org.uk



According to the Passivhaus Institute's WIKI (Passipedia) a study by Kolmetz (1996) informed the development of this summer comfort parameter where >25°C remains less than or equal to 10% of the year. In addition to this, for reasons of accuracy, the daily temperature fluctuation caused by solar gains should not exceed 3Kelvins.

For more information, go to http://www.passipedia.org/basics/summer

A Context for Assessing and Modelling Summer Comfort:

None of the standards examined above, including Passivhaus, specify the assumptions that should be used when assessing a building for overheating at the design stage. These assumptions have a huge impact on the results of any overheating assessment and will be project and occupant specific. They include variables such as occupancy, type and number of appliances, availability of night ventilation and the availability and correct use of moveable shading such as external blinds. Incorrect and unrealistic assumptions often mean overheating is far more likely to happen in practice. Indeed, the more precise the model the more precise the assumptions need to be to give meaningful results. For example, it is common for dynamic models to assume windows will be opened by occupants once indoor temperatures reach 22°C. But more often than not this assumption will be precisely wrong as (in practice) occupants will do something else.

In essence steady state tools, such as PHPP, can be accurate enough simply because they are tolerant of vagaries such as the daily weather and to some extent human behaviour. At this point it is worth noting that the Passivhaus Standards summer comfort assessment is based on total-hours-per-annum because a simple steady state model using monthly data, such as PHPP, cannot calculate hour-by-hour performance. For the purposes of modelling this technique is a lot simpler and, somewhat counter intuitively, can be more realistic.

CIBSE guide A (section 1.5.3.2 and CIBSE TM52 to which it refers) is based upon an adaptive comfort model in BS EN 15251. CIBSE TM52 (4.2) and recognises that, due to the wide range of comfort temperatures permitted, comfort standards based upon an adaptive comfort model present a design problem. For this reason, it also introduces an exceedance threshold.

Conversely CIBSE, as well as Mulville and Stravoravdis (2016), recognise that because comfort is inherently imprecise the selection of a single temperature, or hours of exceedance metric, is also not without issues.
Papers presented at the 2015 and 2016 International Passivhaus Conferences examine the summer comfort achieved in buildings designed to the Passivhaus Standard (Wassouf 2015; Bunyesc & Prieto 2015; Style 2016; Kirtschig 2016). A number of these papers examine summer temperatures using the Adaptive Comfort model described in BS EN 15251. The analysis described serves to validate the model used in PHPP, but also the Passivhaus Standard in the context of Adaptive Comfort.

Based on experience, for the purposes of design, the model used in PHPP provides a reliable and simple means of modelling. The authors believe that this should be complemented by a risk management strategy.

Buildings as Systems: When Design and Occupants Collide

The Passivhaus Standard is wildly recognised for closing the winter performance gap; in spite of the wide range of user behaviour we rarely find buildings using much more heat than predicted. People tend not to forget to close their windows in very cold weather, because the impact of cold drafts on comfort is instant.
However, even though winter comfort can be controlled by the heating system, in the UK and much of Northern Europe, summer comfort is usually achieved by passive measures.

Indoor temperatures result from the balance of gains and losses. The gains are largely uncontrolled and come from the sun and internal heat gains such as people and appliances. Cooling is controlled by opening windows, especially at night when it is cooler outside, and sometimes also by deploying moveable shading. In other words, a mechanically passive cooling strategy requires active interventions by occupants.

These interventions may not be intuitively obvious to occupants – particularly to those used to occupying buildings with very different thermal characteristics.

If a building suffers from overheating it may not be clear why this is or who is to blame. Because of the importance of occupant behaviour, it is tempting to blame occupants for overheating problems, but what is it actually reasonable to expect of occupants? In practice, what can reasonably be expected will depend on who is occupying the building, and where that building is located. What is required of occupants will depend very much on the building's design.

Designing for summer comfort

The following section discusses critical aspects of a design that influence summer comfort.

Glazing areas and orientation

The optimisation of glazing is crucial for ensuring a building performs in summer and winter. Fenestration must serve many, sometimes conflicting, functions such as maximising daylight whilst minimising winter heat loss and summer gains or providing views out whilst maintaining privacy. In the context of summer comfort, the main concern is minimising glass area without compromising daylight or views. The Passivhaus Trust guide 'How to Build a Passivhaus' includes guidance and rules of thumb for optimising glazing.

For best summer and winter performance, glazing should be optimised for good but modest daylight but unless budgets are limited, clients and designers will often push for larger areas of glass than are needed for comfort.

Figure 1. Full height glazing (with shading overhang and internal blinds half closed) causing radiant discomfort. Image Nick Grant.

Ventilation

For a building without active cooling, the only cooling available is from ventilating with outside air. In the UK the average outdoor air temperature in summer is usually lower than indoor temperatures. However, for maximum benefit in a heat wave, windows can be kept shut in the day and opened at night when temperatures have dropped, but this goes against most people's intuition. Once indoor temperatures have risen beyond a certain point however, a natural breeze, even if it is warmer, is generally preferable to the slightly cooler but still indoor air which can feel 'stuffy' even though it is fresh. This breeze will increase heat loss from the body and so improves comfort but it may be at the expense of adding heat to the building.

Figure 2. Tilting windows have many advantages but airflow is restricted and should not be over-estimated at the design stage. Image Nick Grant.

In a Passivhaus it is a requirement to have openable windows in all habitable rooms (rooms without windows are considered non-habitual). These can usually be used to provide additional day time ventilation and night time cooling in summer. When windows can be opened fully, high levels of ventilation can be achieved. However, this may not be possible or desirable in all situations. Some common reasons for less-than-expected window ventilation include:

- Noise
- Security fears
- Insects
- Privacy
- Restricted window opening size, especially tilting windows in deep reveals and/or safety catches above ground floor level, leading the designer overestimating air flows.

Figure 3. Bedroom window left closed due to busy road. Image Nick Grant.

Where windows cannot be opened, mechanical ventilation will maintain good air quality. For 'personal comfort levels' the PHPP manual recommends that ventilation rates (however provided) are increased by 50% which can usually be achieved by the mechanical ventilation system if correctly sized. However, this is not always enough to provide sufficient levels of cooling without window ventilation. For MVHR to provide any cooling it must have a summer bypass facility to disable heat recovery when outside temperatures are cooler than inside.

Thus, for buildings where window ventilation cannot be relied on, the design should be tested with only mechanical ventilation for summer. For success this will require very careful control of solar and internal gains.
Increasing mechanical ventilation rates beyond normal design levels results in very significant increase in fan power unless ducts and terminals are oversized. In this situation a small amount of active cooling may be a more economical option in terms of capital and energy costs.

Shading

Where the windows are larger, it may be necessary to regulate the solar gains by closing external blinds or shutters in the day. This requires a high level of awareness and involvement that is not part of our culture in the UK. In addition, the weather in our temperate maritime climate is unpredictable, for example blinds may not be shut on a day that starts out overcast, so there is a risk that when the occupant returns eight hours later they find the house baking hot inside because it's been sunny for the rest of the day.

Figure 4. Smaller windows and ventilated shutters are the norm in hotter climates, but use of shutters is unfamiliar to most people in the UK. Image Mark Siddall.

Thermal Mass

Another challenge is that all buildings, even timber ones, have some capacity to store heat (thermal mass). This means the effect on indoor temperatures of gains and losses is delayed. A delayed response can be beneficial in keeping a building cool in the day and warm overnight. However thermal mass can also make it difficult to reduce the temperature of a building sufficiently if it has been allowed to get too warm.

Thus, the designer may choose to introduce additional thermal mass in a conscious attempt to improve summer comfort. However, the user, by either not understanding this or by being away during a hot spell, might fail to purge the heat each day and only do this once temperatures have become unbearable. By then it will take some time for the building to cool down sufficiently and this could result in one or more hot sleepless nights.

Due in part to the delayed response, the best way an occupant can keep a building cool using passive measures is not immediately obvious and has to be learnt.

Influence of heat gains

Along with solar gains and ventilation heat losses, the correct assessment of internal heat gains is critical to determining summer comfort and overheating risk. But what level of heat gains should the building designer allow for when assessing summer comfort?

Some gains will be influenced by the building design and construction, especially for blocks of flats that are heavily glazed, or have an extensive hot water distribution network and communal lighting. However, other gains will be influenced by the number and type of appliances such as fridges, consumer electronics and clothes dryers, factors that are arguably outside the control of the designer.

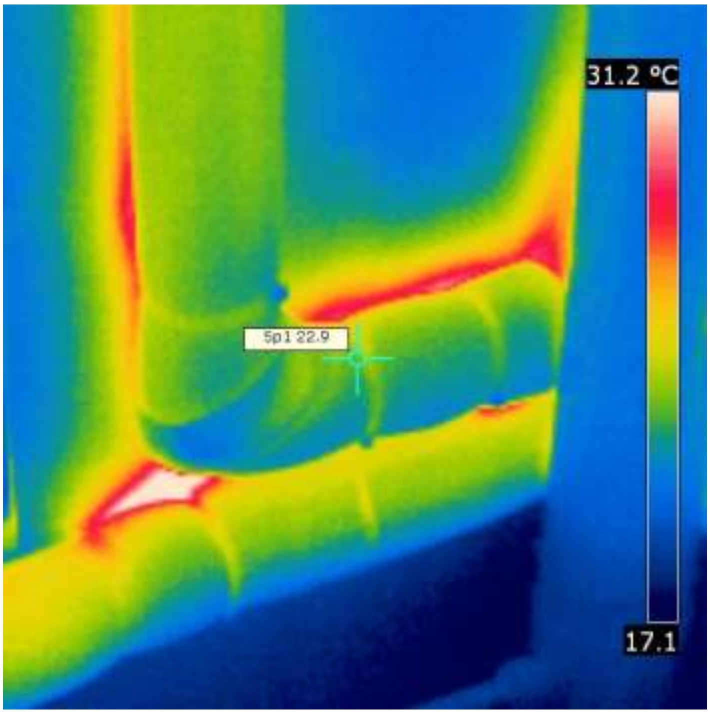


Figure 5. Poorly insulated hot water pipes in a Passivhaus. A significant source of unwanted internal heat gains in summer (see Clarke and Grant 2010). Image Nick Grant.

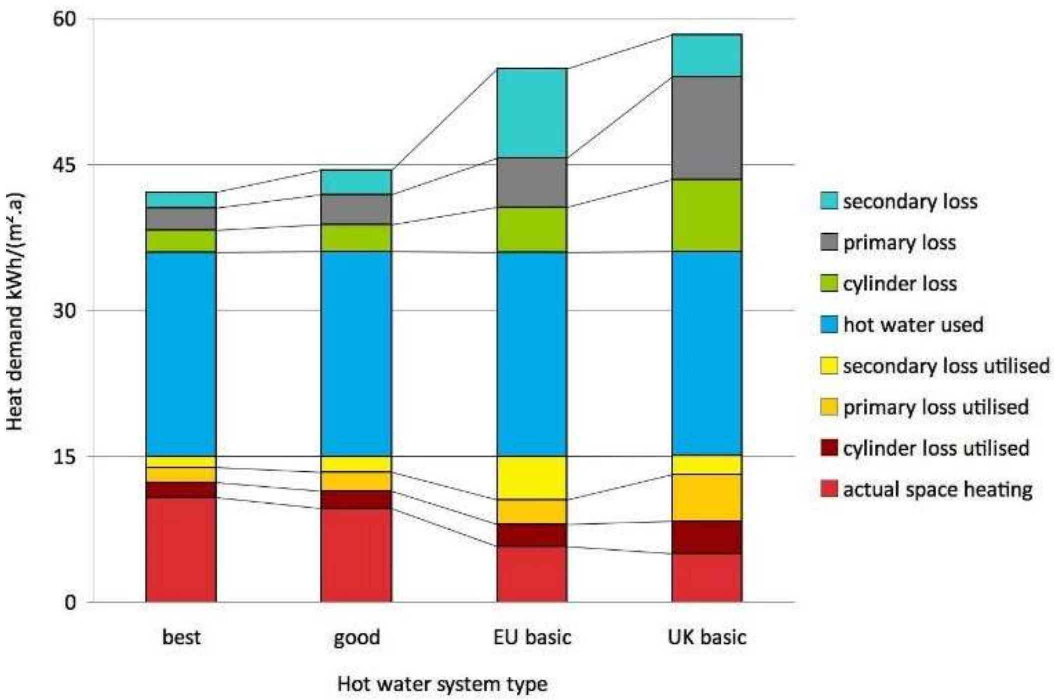


Figure 6. The impact of poorly insulated hot water pipes on energy use (see Clarke and Grant 2010). Image Alan Clarke.

Then we have occupancy, both in terms of number of people but also hours spent at home. This will influence direct gains from body heat but also the amount of cooking and other heat generating activities.

The compounded variables in both design and behaviour result in a large range of potential outcomes, all contribute to overheating risk so where does responsibility lie when a building overheats?

One precautionary response might be to take the worst case scenario imaginable but it is quite likely that this will indicate that active cooling is always required. Here we look at the behaviour of a real Passivhaus dwelling, modelled under various ventilation design and occupant behaviour scenarios, to show how these can interact to provide – or fail to provide – summer comfort.

Influence of heat gains and behaviour: Summer comfort scenarios

The study below is based on a detached Certified Passivhaus with proven summer comfort. It shows predicted performance for a range of conditions using PHPP9 (2016). Monitored data and the following stress testing of the dwelling show it to be relatively robust in terms of summer comfort. Smaller dwellings (flats and apartments) are likely to give more dramatic responses. Monitoring has demonstrated that the house more of less conforms to the predictions. For example, in 2014, the warmest year on record at that point, the house exceeded 25°C for 2% of the eleven-month monitoring period (November to September), whereas PHPP predicted internal temperature would not rise above 25°C at all.

Figure 7: Steel Farm used for scenario analysis. Image Mark Siddall.

Base Case:

- House located in an Area of Outstanding Natural Beauty (AONB). Strict planning conditions restricted the possible aesthetic options such as external shading devices. Deep window reveals are used to provide shading.
- There are no noise or security issues but flies could be a concern in summer.
- Occupancy loads based upon 5 people. The house can accommodate 5 occupants comfortably. Using PHPP9 calculated occupancy of 3 people. In practice there are two occupants. (Family gatherings could result in 14 adults and 8 children.)
- MVHR system used to provide fresh air, temperature controlled summer bypass mode in operation. (In recognition of guidance in How to Build a Passivhaus: Rules of Thumb (Passivhaus Trust) calculations included for the imperfection of summer bypass i.e. they included for some heat recovery taking place.)
- A reasonable level of thermal mass has been provided (108 Wh/K per m² TFA)
- For design purposes no window opening was assumed (though in practice it is possible).
- Clothes drying by indoor washing line.
- Internal gains using PHPP9: 2.4 W/m² (standard), 2.6 W/m² (calculated as-built).

In order to stress-test the existing dwelling a number of scenarios were investigated to assess the impact of changes to the ventilation strategies and internal gains. Table 1 below describes the range of measures and the results.

Note that these scenarios are provided to illustrate the sensitivity of models to a number of operational variables and actual results will depend on the specifics of each building design and climate zone. The 5W/m² internal gains column indicates summer performance should the number of electrical appliances be much higher than assumed during design. For this 150m² home this equates to an additional 8.6 kWh/d of electricity consumption in the summer. Some smaller densely occupied buildings may have higher specific gains but also higher ventilation rates etc.

In all the examples the MVHR is assumed to be left running all summer and this is highly recommended to ensure good air quality. The additional electricity use is very small.

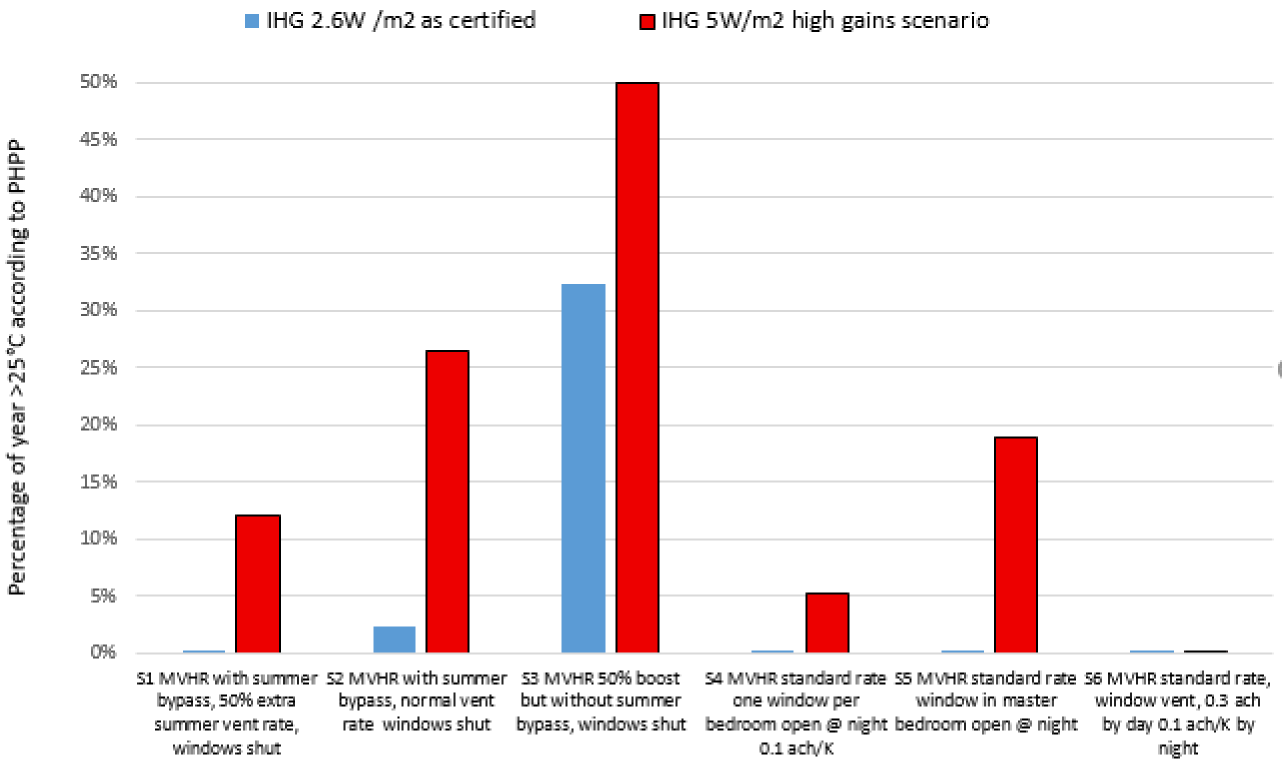


Figure 8. Graph showing overheating risk arising from various design scenarios. In the graph above the vertical axis shows the percentage of the year that the temperature is predicted to be greater than 25°C according to PHPP. The horizontal axis identifies the scenario.

Table 1:

	MVHR (with summer bypass unless stated)	Window vent air-changes per hour per K (for night vent)	% hours per year over 25°C	
			2.6 W/m^2	5 W/m^2
S1	50% extra vent rate	Closed	0%	12%
S2	Normal base vent rate	Closed	2%	27%
S3	50% extra vent, no summer bypass	Closed	32%	50%
S4	Standard vent rate	1 window per bedroom 0.1 air-changes/h/K night vent	0%	5%
S5	Standard vent rate	Only master bedroom window open 0.03 air-changes/h/K night vent	0%	19%
S6	Standard vent rate	0.3 air-changes/h by day and 0.1/air-changes/h/K at night	0%	0%

Commentary upon analysis

Scenario 1 is the base case as designed and described above. The 50% additional summer ventilation that is a Passivhaus design recommendation is provided through the MVHR which incorporates automatic summer bypass. Windows are assumed to be closed.

Scenario 2 shows what happens if the ventilation rate is left at the standard winter setting but no windows are opened to increase general ventilation in summer. For this particular building we see that overheating is not a problem although we see the hours of summer comfort decrease. We can also see that if internal heat gains are much higher, then catastrophic overheating occurs.

Scenario 3 demonstrates the importance of summer bypass. In this situation catastrophic overheating occurs in both low and high internal gain conditions. Without summer bypass the result on overheating is almost the same as leaving the ventilation switched off (see Passipedia for the explanation). Some ventilation units do not include automatic summer bypass and so will be ineffective for maintaining comfortable temperatures in summer. It may be possible to replace the heat exchanger with a bypass core but will this really happen unless the occupant is an enthusiast? This highlights the importance of understanding demands that design decisions impose upon end-users. Alternatively, the MVHR may be run in extract-only mode but there is no guarantee that air infiltration will occur where it is needed. If windows are opened, then summer comfort can be maintained and the mechanical ventilation will still ensure good air quality when windows are shut.

Scenario 4 shows that a modest amount of night ventilation in each bedroom allows good comfort, even with higher gains.

Scenario 5 shows what happens if only the master bedroom window is opened (at night). The MVHR still maintains summer comfort under the standard IHG scenario but higher gains lead to catastrophic overheating.

Scenario 6 included window ventilation by day and additional ventilation by night. All is well, even with the high internal gains scenario, but is this a realistic set of assumptions that occupants will be content with? Designers beware. On another site in another location (say, urban), these assumptions may prove unacceptable.

The Design Paradox: Freedom and Control in Good Design

One response to the analysis so far would be to insist, through regulations or Passivhaus Certification, that all buildings are designed to deliver good summer comfort for the most sensitive occupants independent of external factors such as noise. Such an approach would be unacceptably prescriptive, very costly and may require active cooling to guarantee compliance – yet in many instances it would be unnecessary.

In his book the House Builder's Bible, Mark Brinkley observes that when building a dwelling it can meet any two of the following conditions, but not all 3; cheap, good and quick to build. Similarly, when designing for summer comfort, we suggest you can choose up to 2 of the following. Cheap, low user input and lack of design constraints. If you want all 3 then comfort is likely to be compromised.

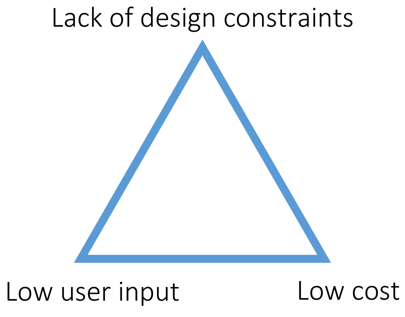


Figure 9 Choose any two. Grant and Siddall.

We can consider some simplified fictional case studies based on real examples.

Example; Low Cost + Low User Input
If we are designing urban social housing on a tight budget then we might choose low user input, and low cost. The successful design is likely to be constrained in terms of orientation which will have an impact on fenestration options. Not being able to rely on users operating or maintaining expensive external blinds, or wanting to follow a prescriptive night ventilation strategy in a noisy urban environment, we will have to limit glazing areas whilst also needing to achieve good daylight and views.

Example; Low Cost + Design Freedom
Another brief might call for a cost effective build on a rural site with a beautiful view to the West but where the client is willing and able to operate external blinds and open windows for night cooling as needed. Also as the desire for a West facing living room with a generous window was the client's desire they might accept the need to work harder to keep the building comfortable in summer as well as tolerating any shortfall in performance during heat waves, perhaps moving into the garden when the living room is too hot! It is essential of course that this is discussed and agreed with the client early on in the design process.

Example; Few design constraints
Another example might be where the design is very much driven by the visual form resulting in a complex articulated building. The high form factor means that it is difficult to meet the Passivhaus annual heating demand without adding additional south glazing and this in turn leads to a high overheating risk. The designer then needs to evaluate acceptable solutions and perhaps revisit the form to see if a more elegant solution can be found. Fixed overhang shading elements may not be visually acceptable but the assumed high budget might stretch to automatic external blinds and other less visible measures.

Example; constraints embraced
Compromises can be avoided if the design is informed by constraints. The designer Charles Eames said: "Here is one of the few effective keys to the design problem — the ability of the designer to recognize as many of the constraints as possible — his willingness and enthusiasm for working within these constraints. Constraints of price, of size, of strength, of balance, of surface, of time and so forth." This approach leads to the development of a vernacular for a high performance building.

Once again, in all cases the costs (money and time) and benefits of the various options should be identified and discussed at the early design stage so that conscious choices can be made before it is too late to make changes. The first summer of occupancy is not the time to explain that for the building to be comfortable all the windows should be opened every time the temperature reaches 22°C!

Conclusion

To maximise summer comfort and minimise the risk of overheating, design teams and clients need to act responsibly and complete the PHPP using realistic parameters. If this is not done, the PHPP's ability to alert designers to overheating risks will be impaired. One of the potential benefits of any certification process is the third party review of design decisions. It is on this basis, when a certifier is engaged, that clients can be reassured overheating risks are being given appropriate scrutiny. Overheating risk are taken seriously and changing PHPP calculations to conceal risks will not be tolerated by certifiers.

Whilst the Passivhaus certification process challenges designers by encouraging them to achieve summer comfort and address overheating risks in a realistic manner, the final responsibility lies with the design team.

It is strongly recommended that a **Summer Comfort: Risk register and Design Statement** are completed (See Appendix 2 & 3) when designing a Passivhaus. Templates can be found on the Passivhaus Trust Knowledgebase www.howtopassivhaus.org.uk

Appendix 1: Technical Appendices for Designers

Limitations of the PHPP

PHPP 9 includes a number of improvements that are particularly helpful in terms of designing for summer comfort in all climates and the authors recommend using this version for design.

The PHPP has a reputation for high levels of accuracy as a design tool for assessing space heating demand. This accuracy is achieved using a relatively simple monthly degree day model albeit refined by field measurements over many years and backed-up by dynamic simulations. Famously the PHPP even estimates the heat lost from flushing the WC and from the evaporation of water from drying towels and plants.

Similarly, correctly used, the PHPP is a powerful tool for assessing summer comfort conditions in a wide range of climates including those requiring cooling and dehumidification. With these acknowledgements made it is important to recognise that PHPP, like other tools, has a number of limitations and considerations that influence the design process.

PHPP is a single zone static model

PHPP is a single zone, static spreadsheet model, as a consequence it ignores localized hot spots in favour of giving a whole building assessment of overheating risks. For most dwellings and even some larger non domestic buildings this is a reasonable simplification. The accuracy of the model decreases where there are large varying or highly localised inputs of heat such as from densely occupied work spaces or highly glazed rooms.

This means further, usually dynamic, analysis is often required when assessing overheating risks in large and complex buildings. However, in parallel with dynamic simulations by others, many PHPP users are gaining experience in the use of the software as a quick and easy to use tool that provides additional insights into summer performance of larger buildings (Encraft 2016). What we find is unnecessarily complex designs that require dynamic simulation are more likely to suffer from summer comfort problems than buildings that lend themselves to a steady state assessment by PHPP.

Since PHPP 8, overheating risk analysis has considered internal gains arising from electrical appliances and Domestic Hot Water (DHW) systems based on building specific data entered in the PHPP (Grove-Smith, Schnieders, 2013). However, internal heat gains used for assessing summer comfort rely on the designer inputting realistic electrical appliances and hot water system design. Summer ventilation by window opening is a free user input that has a dramatic impact on overheating hours. In reality, similarly moveable shading (blinds) can be specified in PHPP but may not be used correctly in practice.

Controlling Overheating: Design Stage Stress Tests

Stress testing your design is vital in any well insulated building. This remains the case for all Passivhaus buildings constructed in the United Kingdom and Ireland. Page 10 of the Passivhaus Trust guide “How to Build a Passivhaus: Rule of Thumb” gives details about critical design considerations. This guidance should be followed on all projects.

For example, it is not sensible to overestimate shading as this can conceal overheating risks. Within PHPP there are a number of opportunities to manage and control summer comfort and overheating risks. In essence there are two primary components:

- Design considerations (window area, thermal mass, internal gains, shading etc.)

- Behavioural considerations, (electricity use, number and extent of window opening, cross ventilation, stack ventilation etc.)

Example results:

The results below are from modelling in PHPP of a block of 50 flats in Exeter. Note that for each example one variable is isolated, for example internal heat gains. The absolute results are project specific and determined by a given set of assumptions. As such they help to develop an understanding of how sensitive a particular design is to overheating.

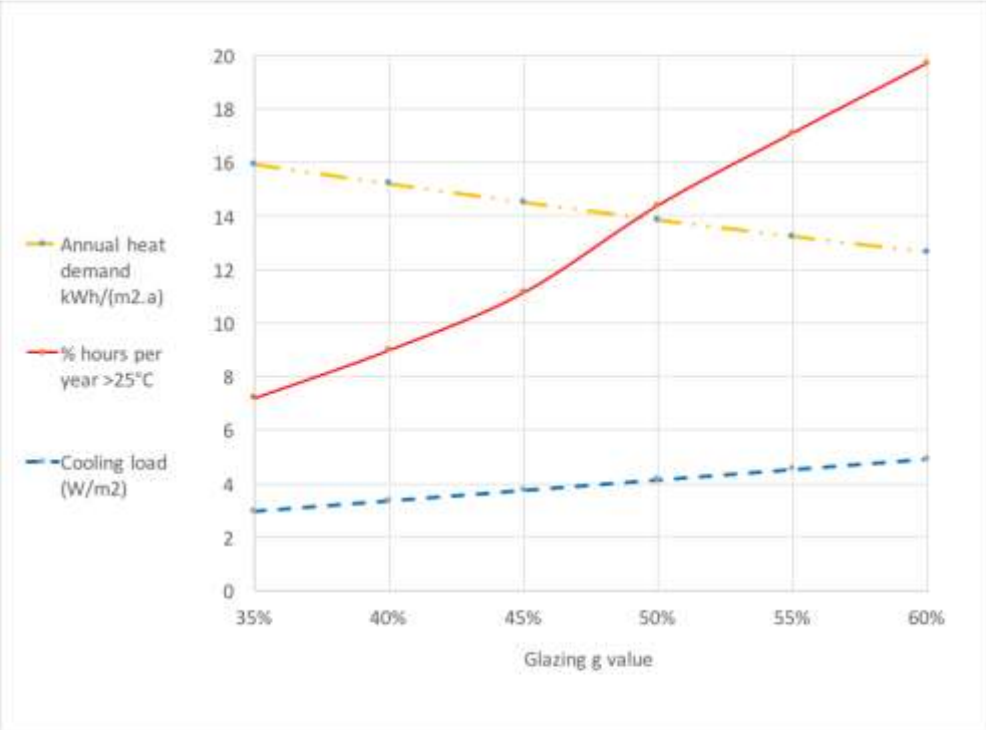


Figure 1. Exploration of the trade-off between glazing g value on annual energy demand and summer comfort test of a design for extra care flats. In later design iterations, the overheating was reduced through other measures.

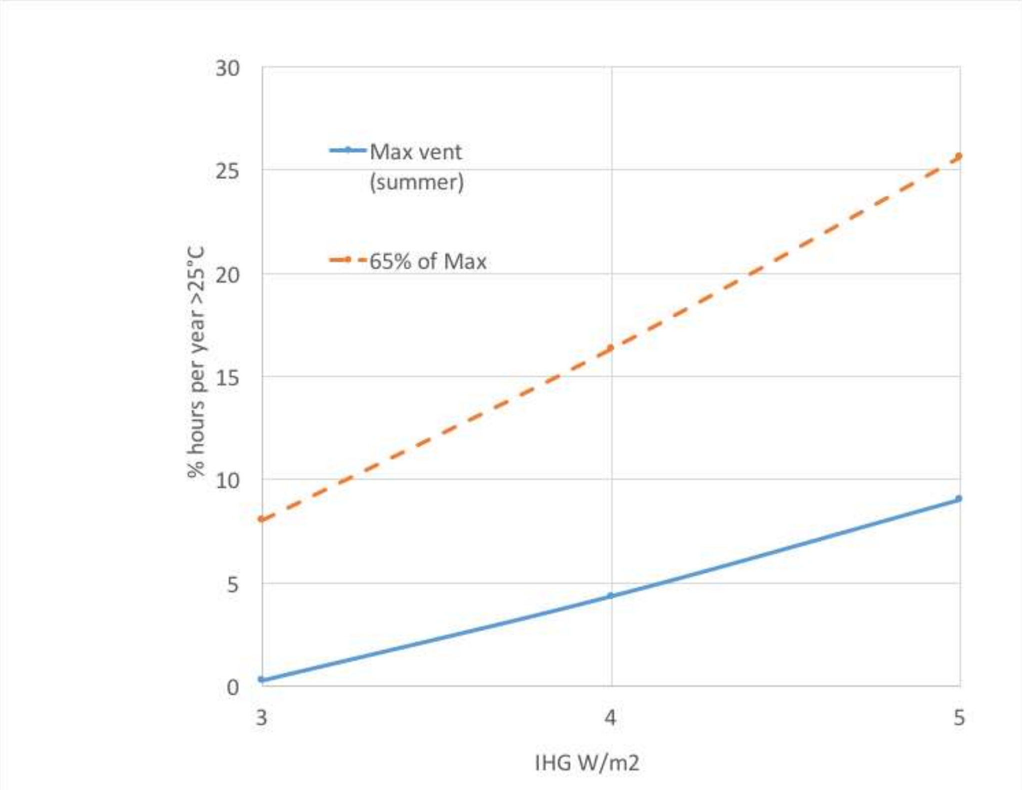


Figure 2. Impact of internal Heat Gains (IHG) on overheating for standard (winter) and boost (summer) mechanical ventilation rates. Extra care flats modelled without window ventilation.

Appendix 2: Controlling Overheating: A Model for a Management Process

Not all factors affecting overheating risk can be modelled using energy modelling tools such as PHPP. For this reason, in addition to modelling, the assessment of overheating risks benefits from a carefully considered management process. This is particularly the case when designing large and complex buildings.

It is suggested that clients and design teams work together and create an overheating risk register.
The register would identify:

- The overheating parameter being considered e.g. noise from outside, intrusion of insects, fear of crime etc.
- The behaviour/opportunity for cooling that could be affected by the parameter.
- The predicted likelihood of the parameter influencing occupant behaviour. For example, on a site with high levels of traffic noise the frequency of window opening during hot weather is likely to be reduced.
- The severity of the impact that adverse occupant behaviour could have upon overheating risk. (PHPP could be used to inform this understanding.)
- The activity that can be undertaken to manage the risk
- The action taken to mitigate the risk

An example of a completed risk register for an urban apartment complex is given below. A blank version of the risk register is provided in Table 4.

Parameter	Behaviour/ Opportunity Affected	Likelihood	Severity	Risk	Risk Management Activity	Design Action/s Arising
NOISE						
Noise from outside	Window vent.	*5*	*4*	*20*	*Consult acoustician to minimise noise intrusion*	*Client to appoint acoustician*
Ground floor ventilation only?	Window vent.	*5*	*4*	*20*	*Design in secure night time ventilation*	
Vehicles	Window vent.	*5*	*4*	*20*	*Consult acoustician to minimise noise intrusion*	*Client to appoint acoustician*
Pedestrian passers-by at night	Window vent.	*5*	*4*	*20*	*Consider opportunity for secure night ventilation*	
Lack of opportunity for secure night ventilation	Window vent.	*5*	*5*	*25*	*Consider mech vent/cooling strategies*	*Scenario planning of options*
Indoor mechanical noise	Switching off/down of vent. system	*4*	*4*	*16*	*Review acoustic standards and design*	*Act based upon review*
Breakout noise from MVHR into adjacent dwellings	Neighbouring dwellings keep windows closed – resulting in overheating	*4*	*5*	*20*	*Review acoustic standards and design to minimise breakout*	*Act based upon review*
OBSTRUCTIONS						
Will internal doors be left open?	Ability to cross ventilate	*4*	*5*	*20*	*Consult owner/occupier*	*Revise strategy accordingly*
Will curtains/ blinds obstruct vent strategy?	Window vent.	*4*	*5*	*20*	*Review design. Consult owner/occupier*	*Revise strategy accordingly*
Size of the ventilation opening dim. realistic?	Window vent.	*4*	*5*	*20*	*Review opening light to reveal/head dims*	*Revise calcs accordingly*
Will insect mesh obstruct ventilation?	Window vent.	*4*	*5*	*20*	*Review design. Consult owner/occupier*	*Revise strategy accordingly*
PERCEIVED SECURITY						
History of crime	Window vent.	*4*	*5*	*20*	*Provide secure night time ventilation*	*Design secure ventilation opening*
Ground floor ventilation only?	Window vent.	*5*	*4*	*20*	*Provide secure night time ventilation*	*Consider site specific strategies*
Passers-by (daytime)	Window vent.	*4*	*3*	*12*	*User guide explains to open windows*	*Update user guide*
Passers-by (night time)	Window vent.	*5*	*4*	*20*	*Provide secure night time ventilation*	*Consider site specific strategies*
Privacy/overlooking	Window vent.	*3*	*4*	*12*	*Consider whether perceived lack of privacy could impact upon perceived security*	*Develop options examining how perceived privacy can be improved*
Lack of opportunity for secure night ventilation	Window vent.	*5*	*5*	*25*	*Consider mech vent/cooling strategies*	*Scenario planning of options*

Intrusion of insects	Window vent.	*4*	*3*	*12*	*Inclusion of insect mesh*	*Recalculation of open area required*
USABILITY AND ACCESS						
Windows	Window vent. Access hard to reach	*3*	*4*	*12*	*Consider changing level of sills and ironmongery*	*Review sill min. heights*
MVHR Summer Bypass	Controls prove more complex than intended	*4*	*4*	*16*	*Consider a range of controls.* *Consult 10-20 occupants*	*Obtain functional samples* *Stage consultation event*
Automatic Summer Bypass not included in design	User fails to manually adjust unit to summer bypass mode	*5*	*5*	*25*	*Include automatic summer bypass*	*Change specification/ design*
SINKS AND STORES						
Thermal mass						
Moisture						
GAINS AND LOSSES						
Window to wall area ratio	Ability to control overheating	*4*	*5*	*20*	*Make windows smaller*	*Review daylighting calcs*
Internal gains higher than expected	Equipment	*5*	*5*	*25*	*Develop and review schedule of appliances etc.*	*Recommend low energy appliances*
FLOOR PLAN						
Opportunity for cross ventilation						
Opportunity for stack ventilation						

Table 3: An example of an overheating risk register.

In Table 3 above a numerical value has been assigned to assess the Likelihood, Severity and Risk (Scale 1-5 where 1=low risk, 5=high risk).

Appendix 3: Design Statement

In order to confirm summer comfort can be achieved it is suggested designers provide a simple statement identifying the critical assumptions that underpin the design.

Below is an example of a completed design statement for a detached house in a semi-rural location.

Example of completed Design Statement for the Management of Overheating Risks:

To provide summer comfort and minimise the risk of overheating, assumptions have been made. In consultation with the project team, including the client and user group representatives, the following conditions apply:

Building Type: Residential
Utilisation pattern: Dwelling

1) Automatic summer bypass (provided by the MVHR unit) is the primary means of providing cooling (i).
2) Window opening activities have been minimised. It has been assumed that ventilation will be used at night (ii). Openable windows have been provided in each room. Window stays permit controlled ventilation.
3) Internal heat gains from lighting and electrical appliances have been and will be minimised (iii).
4) Design occupancy has been assumed to be 5 people (iv).
5) External shading mechanisms are manually controlled (v).
6) No active cooling is provided (vi).

On the understanding that these conditions are met it is predicted that the operational temperature of the building will not rise above 25ºC for more than 1 % of the year.

Where these conditions are not observed summer comfort will be compromised and overheating risks will increase.

Technical Clarifications:

i) The ventilation rate is at least 0.45 air changes per hour.

ii) Night time ventilation is assumed to provide a maximum cooling of 0.1 ac/K. This ventilation rate will be provided for 12 hours each night. As viewed from the inside, the inward opening windows provide a minimum of 50mm of clear opening has been provided at the window head and jambs. (Refer to construction details: 6975/DE/031/001, 6975/DE/031/002, 6975/DE/031/003)

iii) Based upon the PHPP IHG worksheet it has been assumed internal gains are less than 2.6 W/m^2.

iv) The User Determined Occupancy has been used for assessment (rather than 'Standard')

v) The assumed summer shading reduction factor has been derived from (Refer to construction details: 6975/EL/020/001, 6975/EL/020/002, 6975/EL/020/003)

vi) The cooling load has been mitigated by passive measures.

Table 5: Example of Design Statement

Appendix 4: Responsibilities for Clients, Designers, Occupants and Certifiers

Client Responsibilities

To help ensure a successful outcome clients need to engage in the design process. In doing so they need to develop an appreciation for not only the design of the building but also the way occupants will use the building.

Making sure that the design team has the right skills, knowledge and experience in place is vitally important. Refer to Passivhaus Quality Assurance: Large and Complex Buildings (Siddall, 2015) for more details.

Design Responsibilities

Whatever modelling method is employed, a clear record of the assumptions used should be provided at an early stage in the design process. Any specific requirements relating to products (for example window free open areas) should be identified and made clear.

For overheating to be controlled it is important that one person is responsible for managing and coordinating overheating risks. It makes sense that this may the person responsible for building the PHPP model, though on larger projects it may be another member of the project team.

Where there is a split between management and coordination and the construction of a PHPP model it is important that good lines of communication are maintained.

It is recommended that consideration should be given to second generation owners that are unlikely to benefit from close support and carefully planned handover procedures.

Occupant Responsibilities

In practice building occupants play a vital role in helping to prevent overheating risks. It stands to reason that where occupants have the opportunity to contribute to the design process then there is the greatest opportunity for success. This is because likely and realistic patterns of behaviour can be discussed, explored and modelled using PHPP.

However, it is not always possible to engage with the eventual occupants of a building. Where this occurs scenario planning plays an even more important role. It is vitally important that designers err on the safe side and assume low levels of engagement with the building.

Building Certifier Responsibilities

It is not the Certifiers responsibility to ensure that overheating will not occur. Their role is to do two things:

1) Review the design proposal and question whether the assumptions underpinning the design are grounded in sound design principles
2) Confirm that the PHPP calculations conform to minimum requirements.

This means the Design Team will have to confirm they have interrogated the design robustly and that the design assumptions underpinning the PHPP calculations have been agreed with the Client and, wherever possible, the occupant.

Any failings in the design assumptions that are identified once the building is occupied are the responsibility of the design team. If in doubt or concerned about overheating risks the design team should consult their certifier.

References

Bunyesc J., Prieto S. (2015) "Several examples of monitored Passive House homes from the Mediterranean to the Pyrenees, Proceedings of the International Passivhaus Conference 2015, Passivhaus Institute.

Butcher B.; Clarke A.; Godber S.; Grant N.; Hines J.; Jennings P.; Parsons C.; Siddall M.; (2015) How to Build a Passivhaus: Rules of Thumb, Passivhaus Trust, March 2015.

CIBSE (2016) Guide A: Environmental Design, CIBSE, June 2016 .

Clarke A.; Grant N.; (2010) The importance of hot water system design in the Passivhaus, Proceedings of the 14th International Passivhaus Conference 2010, Passivhaus Institut.

Encraft (2016) Strategies for mitigating the risk of overheating in current and future climate scenario

Grove-Smith J.; Schnieders J.; (2013) PHPP Calculations in Hot and Humid Climates, Proceedings of the 17th International Passivhaus Conference, 19-20th April 2013.

Kirtschig T. (2016) Measurements results from Energon in Ulm, Proceedings of the International Passivhaus Conference 2016, Passivhaus Institute.

Krebs J.; Frankhauser S.; Hall J.; Johnson A.; Parry M.; Wyne G.; (2014) Managing climate risks to well-being and the economy [accessed 06/02/16] https://www.theccc.org.uk/wp-content/uploads/2014/07/Final_ASC-2014_web-version-4.pdf

Leaman A.; Bordass W.; (1997) Strategies for Better Occupant Satisfaction, Fifth Indoor Air Quality Conference

Passivhaus Institute (2015a) Passivhaus Planning Package version 9. Passivhaus Institute

Passivhaus Institute (2015b) Passipedia [accessed 06/02/16] http://www.passipedia.org/basics/summer

Siddall M. (2015) Passivhaus Quality Assurance: Large and Complex Buildings, Passivhaus Trust, March 2015.

Mulville M. Stravoravdis S. (2016) The impact of regulations on overheating risk in dwellings, Building Research and Information

Schnieders, J (2015) Internal Heat Gains in relation to living area. Available on Passipedia http://goo.gl/4pSpGu

Style O. (2016) Measured performance of a lightweight straw-bale Passive House in a Mediterranean Climate heat wave, Proceedings of the International Passivhaus Conference 2016, Passivhaus Institute.

Wassouf M. (2015) Comfort and Passive House in the Mediterranean summer – monitorization of 2 detached homes in Spain, Proceedings of the International Passivhaus Conference 2015, Passivhaus Institute.