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# Technical Insight

**December 2015**

## Strategies for mitigating the risk of overheating in current and future climate scenarios

***Applying lessons from Passivhaus to contemporary housing***

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**Summary**

*The importance of designing domestic buildings to perform well in both winter and summer in terms of energy efficiency and comfort is being recognised as key to good design. In summer, well-insulated buildings are at risk of overheating if not effectively shaded and ventilated and this risk is likely to increase with the effects of climate change – posing potentially serious health risks to residents.*

*By modelling different Passivhaus standard buildings, over a range of future climate scenarios, insights can be found into which measures to control overheating may be necessary. These recommendations apply equally to 'standard' buildings, particularly as building regulations tighten.*

*Software models used to calculate the risk of overheating have their advantages and disadvantages. The key is to apply models appropriate to each specific situation. While a single result may not tell the full story in terms of the risk of overheating that occur (and particular care must be taken with multi-residential buildings) competent analysts using appropriate models effectively can identify cost-effective measures that significantly reduce the risks in most situations .*

## Introduction

Climate change is predicted to have far reaching and unpredictable consequences for many people in most industries and locations in the UK and the wider global community. Attempting to model and plan for these consequences is notoriously challenging and may dictate the success and failure of some industries in the upcoming decades. With respect to the built environment, this poses a number of challenges for not only trying to reduce the greenhouse gas emissions associated with buildings, but also designing them so that they perform well over their whole lifetime. In the context of a changing climate, the long lifetime of buildings (often over 100 years) means that careful thought to all aspects of design is important to ensure lasting performance.

A typical UK future climate scenario (*medium emissions at 50% probability level – see below for details)* modelled for the year 2080 is predicted to have the following general qualities, with respect to the current climate, which are widely seen in most likely future climate scenarios[1]:

- **Warming in all areas of the UK, to a greater extent in summer than in winter and to a greater degree in the south of England than the north of Scotland.**
- **Higher daily maximum temperatures as well as warmest day of the year temperatures.**
- **Higher mean daily minimum temperatures**
- **Changes to precipitation levels and cloud cover patterns across the UK (some increases and some decreases depending upon location)**

One consequence of these warming temperatures, particularly in summer, is that buildings may be likely to overheat. Improvements to Part L of the Building Regulations in the UK over the past decade have led to higher levels of insulation, better levels of airtightness and higher performance double or even triple glazed windows. These measures are vital for retaining warmth in the winter and reducing building energy consumption a great deal. However, the reverse of this is that in summer excessive solar gains may enter the building where they then remain, leading to sometimes dangerous levels of overheating. Finding suitable techniques to model and predict performance of buildings in future climates as well as solutions to passively avert overheating issues is therefore of high importance, not only for health and comfort reasons, but also to prevent costly and energy intensive cooling services being added to buildings a short time into their lifetimes. This study aims to investigate the increased risk of overheating in future climates and identify which measures should be implemented at which times to avoid these risks.

## Overheating

Throughout this report the definition of the frequency of overheating is 'the percentage of hours per year that the interior ambient temperature is above 25°C'. The Passivhaus standard (see below) recommends that this frequency should not surpass 10% to maintain comfort. This definition is not the only definition available and other, more detailed, methodologies (e.g. CIBSE) exist which use different temperatures and time periods to define overheating.

[1] Jenkins, G. J., Murphy, J. M., Sexton, D. M. H., Lowe, J. A., Jones, P. and Kilsby, C. G. (2009). *UK Climate Projections: Briefing report*. Met Office Hadley Centre, Exeter, UK


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**Ambiguity also exists between defining overheating for comfort reasons or for health reasons.** Numerous factors affect the perception of overheating and comfort by residents including temperature spikes, extended periods of warm weather, radiative asymmetry within the building and draughts. As a result a fixed definition of overheating does not always even correspond to feedback from occupants and more research in this area is certainly still required.

Likewise for health reasons, numerous issues that are not clearly understood blur the definition of overheating. Certainly, people have adapted to live in climates much warmer than the UK (even as it will be in 2080!) so there are issues of adaptation as well as vulnerability of the elderly, the young and the ill. Heat related illness, however, has been shown to be responsible for 35,000 deaths over the summer heatwave of 2003 in Europe[2], so for this reason alone, overheating must certainly be considered in the design of houses in the future.

## Passivhaus

It must be stressed that a well-insulated building, in itself, is not more susceptible to overheating than a lower quality building as good insulation prevents heat leaving *or entering* the building envelope. It is when high solar gains, through windows, or high internal gains, from appliances or building services, increase internal temperatures that overheating can occur as this heat cannot easily escape without adequate ventilation. Therefore the provision of adequate shading and ventilation is vital in well insulated buildings during the summer months.

This study focusses on overheating in buildings built to the Passivhaus standard (*see 'What is Passivhaus' box right)*. This is a rigorous energy standard which is one of the strictest in terms of low energy demand, comfort and airtightness of any widely used building standard. It is anticipated that as building standards improve in the UK, regulation will close the gap between current building standards and the standards required for Passivhaus

## What is Passivhaus?

*"The heat losses of the building are reduced so much that it hardly needs any heating at all. Passive heat sources like the sun, human occupants, household appliances and the heat from the extract air cover a large part of the heating demand. The remaining heat can be provided by the supply air if the maximum heating load is less than 10W per square metre of living space. If such supply-air heating suffices as the only heat source, we call the building a Passive House."*

***Prof Dr Wolfgang Feist| Passivhaus Institute***

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The performance specification that a Passivhaus must achieve is:

-Heating/Cooling Demand:
≤ 15 kWh/m2/year

**OR**

-Heating/Cooling Load: ≤ 10 W/m2

**AND**

-Primary Energy Demand:
≤ 120 kWh/m2/year

-Air change rate: ≤ 0.6 per hour

-Frequency of overheating: < 10%

[2] 'Overheating and Ventilation in Homes ' – Zero Carbon Hub, March 2014



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certification and therefore that these results will be increasingly relevant for new buildings in the future.

## Weather Data

In order to effectively model buildings, a representative set of climate data is required so that any designs are made as efficiently as possible for the location i.e. correctly sized heating systems, cost-effective insulation thicknesses, appropriate window specification, frost protection etc.

There are a wide range of datasets which have current weather data available. However, this analysis will seek to look at the risks of overheating in future climates so requires data generated from a suitable climate model. One of the most widely used sources of future climate data is the UKCP09 weather model developed by the UK Met Office. This data provides values for temperature changes and other variables but with a corresponding probability so as to ascertain the likelihood of a certain outcome under varying circumstances.

In this study, future weather data produced by the UKCP09 climate model and processed by the Prometheus Project at Exeter University is used to calculate the predicted overheating at three points in the future: 2030, 2050 and 2080 and compare it with current climate data. These datasets are available under two emissions scenarios specified by the Intergovernmental Panel on Climate Change (IPCC), the **a1b medium emissions** scenario and the **a1fi high emissions** scenario. These scenarios are based on a world of world of large economic growth that has a growing population that peaks toward the middle of the century. The a1fi scenario is based on a fossil fuel intensive energy generation model whereas the a1b generates energy from balanced sources, not relying too heavily on any single one. The low emissions scenario, a1t, which uses non-fossil fuel energy sources looks increasingly unlikely so is ignored in this study. Current trends also indicate that targets for the a1b scenario are also currently not being met.

These scenarios can be used to create datasets for a single year in the future for the years 2030, 2050 and 2080 in each case. These yearly weather files are designed to be plausible years but with a warm summer period, ideal for overheating analysis, called Design Summer Years (DSY) and are taken from a statistical random sample of such years at the 50$^{th}$ percentile. A detailed explanation of the above terms and how each weather file is created is detailed in the box below.


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## How the UKCP09 weather generator creates future weather data

The weather generator contains the physical relationships between 16 key climate parameters (including mean temperature, average precipitation, relative humidity etc.) including their feedback effects in the form of 10,000 change factors which form the weather generator probability distribution function (PDF). Using historic weather data from the period 1961-1990 the generator is 'calibrated' to actual data and a weather signal for daily rainfall is generated upon which the other parameters depend. Starting with rainfall, the other climate parameters are calculated over a period of 30 years on a daily scale by sampling randomly from the PDF. This dataset therefore contains the naturally varying weather signal, trained on historic data from 1961-1990, plus the climate change signal created in the weather generator.

## Test Reference Years (TRY) and Design Summer Years (DSY)

To be statistically robust, at least 100 of these 30 year datasets must be created giving in total at least 3000 equally likely future weather years. Using 3000 years of weather data is unwieldy and excessive in most applications, so some standard datasets which are more manageable are often created from this sample. Two common types used by CIBSE are the Test Reference Year (TRY) and the Design Summer Year (DSY).

The TRY is an average weather year which aims to best represent the climate trends via averages which exclude extreme weather. This type of year is often used for energy analysis of buildings. More suited to overheating analysis is the DSY which aims to mimic a 'near extreme' year for high summer (April to September inclusive) temperatures. A DSY is a single contiguous year of weather data which corresponds to the 90$^{th}$ percentile warmest summer period from the selection of weather years generated. A single DSY (and TRY) is generated for each 30 year dataset, so upon completion 100 DSY and 100 TRY weather years will be created.

## Percentiles

One of the key advantages of the UKCP09 weather generator is the fact that it can describe climatic changes with their relevant probabilities. This is done for DSY's by ranking the 100 weather years by average summer temperature, then selecting the corresponding rank as the percentile. Interpreting this means that, in practice, if the 90$^{th}$ percentile weather year predicts a temperature rise of 6°C by 2050 then there is a 90% chance, based on the assumptions of this model, that the actual temperature rise will be *less than* this value. By this logic, the 50$^{th}$ percentile dataset means that it is equally likely that the temperature rise will be above or below the given value and for this reason it is known as the *central estimate* or mean value.

## Modelling Assumptions

The modelling was done using two different software packages:

- **Passivhaus Planning Package (PHPP)**: PHPP is an energy balance package which makes accurate calculations considering a large number of variables from solar gains


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and internal heat gains to losses from thermal bridges and window frames. The calculations are mostly steady state but have been based on and verified by dynamic models as well as real life data. The software, however, has only limited resolution when calculating overheating as it only considers the whole building envelope and only uses monthly average climate data making it unable to assess maximum temperatures on a daily (or hourly) scale.

- **IES Virtual Environment (IES)**: IES is a dynamic energy modelling software package designed to be a comprehensive model via a number of different modules accounting for different analysis areas such as building dimensions, energy modelling, ventilation and airflow etc. IES was initially designed for use in large commercial buildings but is also relevant for use in smaller domestic dwellings due to the ability to programme a large number of parameters. This can make IES difficult to use and accurate models require expertise in the software to input the parameters correctly.

## Weather Data preparation for PHPP

Due to the nature of the energy balance calculation in PHPP, the datasets of future climate data must be prepared specially for it to be used within PHPP. This analysis only considers the summer case to make predictions about the frequency of overheating, so the PHPP climate data was prepared with this in mind. This means that a number of variables can be excluded since they do not affect the summer overheating calculation in PHPP. The assumptions made in preparing the climate data are summarized below in Table 1.

| PHPP input | How it is calculated from PROMETHEUS data | Why assumption is valid? |
|---|---|---|
| Monthly average ambient temperature [°C] | Average temperature from hourly temperature values over the whole month. | Due to long time constant in a Passivhaus (a measure of how long heat remains within the building) average monthly temperatures are acceptable. |
| Monthly irradiance in the cardinal directions [kWh/m$^2$.month] | Existing regional PHPP data is used unchanged in all future climate scenarios. | PROMETHEUS data provides irradiance values but not divided between the cardinal (i.e. N, S, E and W) directions. A dynamic model is required to accurately divide the total received irradiation this way. A previous study (*McLeod, Hopfe and Rezgui, 2011)* has shown that summer variations in monthly irradiance from UKCP09 data are small up until 2080 and highly dependent on cloud cover which is a poorly understood climate variable, so retaining current values is deemed an acceptable approximation. |
| Monthly global irradiance [kWh/m$^2$.month] | Existing regional PHPP data is used unchanged in all future climate scenarios. | See above. |


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| PHPP input | How it is calculated from PROMETHEUS data | Why assumption is valid? |
|---|---|---|
| Dew Point Temperature [°C] | Not Included | As these values are not used within PHPP for the calculation of the frequency of overheating, they were ignored in this analysis. |
| Sky temperature [°C] | | |
| Heating/Cooling Load data [W/m$^2$] | | |
| Ground temperature [°C] | Not part of PROMETHEUS dataset. | Calculated within PHPP based on ambient temperatures |

**Table 1 - Climate variables used in PHPP dataset and how they have been modified from the original PROMETHEUS data**

## Calculation of the frequency of overheating

Modelling was done of two different property types: a pair of semi-detached 3 bedroom houses and a tower block consisting of 3 bedroom maisonettes ( see below Figures 1 and 2). Both dwellings are designed to Passivhaus standard in terms of thick insulation layers, thermal bridge free designs, airtight envelopes, mechanical ventilation and triple glazed windows.

### *Semi-detached dwelling*

The first property type analysed was a typical semi-detached Passivhaus dwelling with 3 bedrooms built using a lightweight timber frame construction. As is typical practice in Passivhaus design, the two dwellings that form the semi-detached unit are enclosed within a single thermal and airtight envelope so consequently are modelled together as one volume of internal space with a treated floor area (TFA)[3] 132.8m$^2$ (i.e. each dwelling has a TFA of 66.4m$^2$). Results for both dwellings combined are presented below. The house design is optimised to meet the climate criteria in Leicester.

[3] Treated floor area (TFA) is a critical value in the Passivhaus calculation methodology to which specific (i.e. per m$^2$) values are normalised. It is normally roughly between 10 and 30% smaller than the gross internal floor area. More details can be found at http://www.olsarchitects.ie/Dwelling_Treated_Floor_Area_Calculation_Guide.pdf


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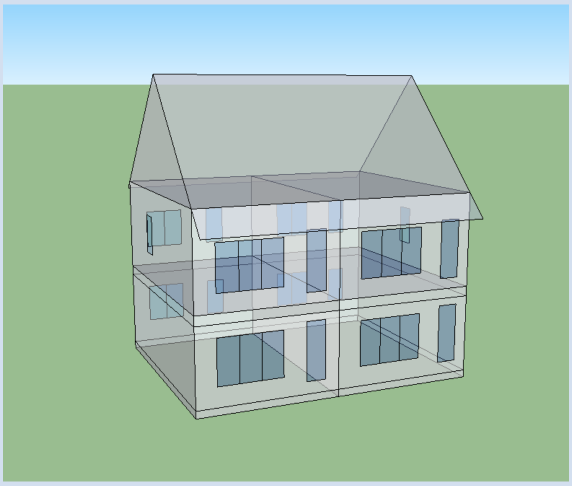

Figure 1 - Semi-detached Passivhaus

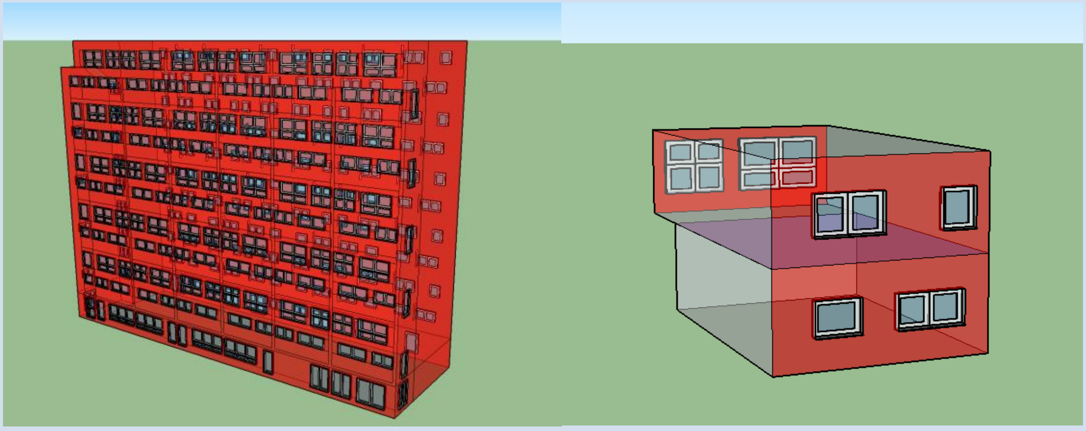

Figure 2 - Tower block with individual flat isolated.

Analysis in PHPP used the modelling assumptions and specification in Table 2:

| Baseline Specification | U-Values (W/m2K): Wall, Roof, Floor = 0.1, Windows = 0.9<br>Airtightness n50: 0.6 h-1 |
|---|---|
| Internal Heat Gains | A profile of internal heat gains is used in the PHPP to represent typical dwellings. Specific white goods can be included in addition to this. In the baseline specification only a washing machine and a combination fridge-freezer are assumed to be present (i.e. no tumble dryer, use of a clothesline is assumed, and no dishwasher) |
| Heating System | A combination gas boiler (no hot water storage) |
| Ventilation | MVHR (Mechanical Ventilation with Heat Recovery) with summer bypass which continues ventilation during summer, but without heat recovery. |
| Solar Gains | Larger windows face south, glazing g-value of 0.61 |


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| | |
|---|---|
| Shading | Window reveal depth 200mm |
| Thermal Mass | Lightweight construction with Thermal Mass Parameter = 60Wh/(m2K) |
| Window Opening | In the baseline specification **four** windows in each dwelling are open on a tilt[4] with 10cm clear opening between frame edge and the casement for 24h/d. |

Table 2 - Specification of semi-detached Passivhaus dwelling optimised for Leicester climate.

Table 3 shows the frequency of overheating, using the above specification, in three different UK locations, using the two different emissions scenarios for future years. Both scenarios use DSY 50 percentile datasets.

| | *Historical* | *2030* | | *2050* | | *2080* | |
|---|---|---|---|---|---|---|---|
| | | Med | High | Med | High | Med | High |
| ***Glasgow*** | 0.0% | 1.7% | 1.7% | 2.5% | 3.4% | 5.2% | 8.2% |
| ***Leicester*** | 0.8% | 5.3% | 5.1% | 7.2% | 8.0% | 11.0% | 13.8% |
| ***Portsmouth*** | 5.5% | 12.5% | 13.4% | 17.6% | 19.9% | 23.0% | 27.2% |

Table 3 - PHPP modelled frequency of overheating for semi-detached Passivhaus dwelling in 3 different locations and 6 different future climates.

This table highlights **the importance of using accurate climate data**, as different locations would normally require different build specifications in order to maintain a comfortable internal environment. This design, optimised for the Leicester location, shows that it remains within the acceptable limit of the Passivhaus standard, as designed, until sometime between 2050 and 2080 before measures are required to reduce its frequency of overheating to an acceptable level. Whilst the design may appear more optimal for the Glasgow location, this result only includes the summertime case and the insulation and glazing is actually optimized for the winter case in Leicester to minimize the heating demand of the building, so if it were designed for Glasgow it would likely need increased insulation to meet the wintertime Passivhaus criteria.

Some typical measures that might be taken to reduce overheating in a dwelling are listed below:

- Increase window opening
- Install internal/external blinds
- Install fixed shading measures
- Install new glazing to limit solar gain

Using the historical climate data for Leicester, these parameters were varied with results given in the below Table 4:

[4] It is normal in summer to have a higher background ventilation rate than in winter to maintain basic hygienic air quality as warmer summer air can quickly become dry. Leaving windows open on a tilt in addition to the ventilation provided by the MVHR (with summer bypass engaged) is the most effective way to achieve this and it is usually possible to lock windows in the tilted position to maintain security.

| | Historical | 2030 | | 2050 | | 2080 | |
|---|---|---|---|---|---|---|---|
| | | Med | High | Med | High | Med | High |
| *No measures* | 0.8% | 5.3% | 5.1% | 7.2% | 8.0% | 11.0% | 13.8% |
| *Increased window opening* | 0.2% | 1.4% | 1.8% | 3.3% | 4.1% | 7.3% | 9.4% |
| *Internal blinds* | 0.2% | 1.5% | 2.0% | 4.0% | 5.0% | 8.9% | 11.0% |
| *External blinds* | 0.0% | 0.3% | 0.4% | 0.9% | 1.3% | 3.9% | 8.2% |
| *Brise soleil over south facing windows* | 0.2% | 1.6% | 2.1% | 4.1% | 5.1% | 8.9% | 11.0% |
| *Low g-value glass (0.37)* | 0.1% | 0.9% | 1.2% | 2.3% | 3.3% | 7.7% | 10.3% |

Table 4 - PHPP modelled frequency of overheating when using individual cooling measures

As can be seen each measure helps reduce the frequency of overheating to a different extent. The **most effective measure in this case is the use of external blinds** which have been shown to be effective in a large number of real life case studies and are a regular design feature in most housing in a number of European countries, although less so in the UK. Installing external blinds will help regulate summertime comfort without affecting solar gains during the winter and will provide protection against overheating, within the acceptable limit of Passivhaus, until beyond the year 2080.

A number of these measures are reliant upon control by the occupant of the dwelling which can limit their effectiveness/reliability in real life. Furthermore, **window opening is not always possible in some areas or situations where it may pose a security risk**. Measures such as fixed shading objects or low-g-value glass require no input from the occupant but are seen to be slightly less effective in this case. They also pose the risk of limiting solar gains in winter when they are required to contribute to the space heating demand of the building.

### *Multi-residential tower block*

The PHPP calculation, as described above, only provides a value of overheating for the whole building and does not give higher resolution as to which individual rooms in the building may overheat more than others. Extrapolating this idea to a tower block with many dwellings highlights some of the limitations of this strategy.

A large tower block was modelled in PHPP containing 34 dwellings over 11 storeys (see Figure 2). The building envelope wraps around the entire tower block so that all 34 dwellings are contained within the same insulation layer. By comparing the modelled frequency of overheating for the entire building envelope (containing all 34 dwellings) and for the case of a single dwelling within that thermal envelope shows significantly differing results and shows the importance of detailed overheating analysis when considering large multi-residential buildings.

The below table (Table 7) shows the modelled frequencies of overheating for the whole building and for the individual dwelling within the tower block, using historical climate data for Portsmouth. The model assumptions are given below in Tables 5 and 6:


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| Baseline Specification | U-Values (W/m2K): Wall, Roof = 0.14, Floor = 2.4, Windows = 0.95<br>Airtightness n50: 1.0 h-1 |
|---|---|
| Internal Heat Gains | A representative profile of internal heat gains based on a survey of the occupants' appliances within the tower block averaged across the building. |
| Heating System | Direct electric storage heaters |
| Ventilation | MVHR (Mechanical Ventilation with Heat Recovery) with summer bypass which continues ventilation during summer, but without heat recovery. |
| Solar Gains | Balanced glazing orientation, glazing g-value of 0.39 |
| Shading | Window reveal depth 190mm |
| Thermal Mass | Lightweight construction with Thermal Mass Parameter = 60Wh/(m2K) |
| Window Opening | In the baseline specification **two** windows in each dwelling are open on a tilt[5] with 10cm clear opening between frame edge and the casement for 12h/d. |

Table 5 - Specification for tower block containing 30 3 bedroom dwellings optimised for the Portsmouth climate.

| | Treated Floor area [$m^2$] | Percentage of external wall glazed [%] |
|---|---|---|
| **Tower Block (34 dwellings)** | **3120** | **29** |
| **Individual dwelling (mid-floor)** | **87** | **40** |

Table 6 - Details of individual dwelling and whole building for overheating analysis

| ***Portsmouth*** | ***Historical*** | ***2030*** | | ***2050*** | | ***2080*** | |
|---|---|---|---|---|---|---|---|
| | | Med | High | Med | High | Med | High |
| ***Whole building*** | **4.6** | **13.2** | **13.2** | **17.2** | **27.7** | **32.4** | **33.4** |
| ***Individual dwelling*** | **15.0** | **23.5** | **25.0** | **30.1** | **32.4** | **34.7** | **36.5** |

Table 7 - PHPP modelled frequency of overheating in Portsmouth climate.

Under the certification criteria of the Passivhaus standard, it is only the value of 4.6% summer overheating in Table 7 that would be considered in the design of a building using PHPP – which is deemed acceptable, but as can be seen by the above results, not only is the individual flat case well above the 10% limit using historical climate data, but even by 2030 both cases quickly show increased levels of overheating, above the acceptable levels.

[5] It is normal in summer to have a higher background ventilation rate than in winter to maintain basic hygienic air quality as warmer summer air can quickly become dry. Leaving windows open on a tilt in addition to the ventilation provided by the MVHR (with summer bypass engaged) is the most effective way to achieve this and it is usually possible to lock windows in the tilted position to maintain security.


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**These large differences between modelled frequencies of overheating in the two different cases clearly show that a tool with higher resolution is required to properly account for the overheating risk in large multi-residential buildings.** The results reflects the fact that whilst, on average the building will not overheat to a large degree during summer, certain areas may overheat whilst others will never overheat, depending on the location and situation of that particular dwelling within the envelope of the building.

Using UKCP09 climate data, the frequency of overheating was modelled in IES VE for a representative building consisting of 30 equally sized dwellings within an envelope with dimensions equal to those modelled above in PHPP. Results are presented below, in Table 8, for the total building overheating as well as for an individual dwelling in Portsmouth, Leicester and Glasgow for the two climate scenarios mentioned above.

| *Frequency of overheating [%]* | *Historical* | *2030* | | *2050* | | *2080* | |
|---|---|---|---|---|---|---|---|
| | | Med | High | Med | High | Med | High |
| *Glasgow – whole building* | 0.1 | 2.0 | 3.3 | 4.4 | 4.5 | 8.1 | 11.7 |
| *Glasgow – individual dwelling* | 0.1 | 3.4 | 5.0 | 6.5 | 7.4 | 11.9 | 16.3 |
| *Leicester – whole building* | 3.1 | 9.0 | 6.7 | 11.1 | 10.7 | 16.2 | 21.1 |
| *Leicester – individual dwelling* | 5.1 | 12.5 | 9.8 | 14.7 | 14.7 | 21.2 | 25.1 |
| *Portsmouth – whole building* | 7.7 | 18.7 | 16.2 | 20.8 | 23.7 | 27.4 | 28.1 |
| *Portsmouth – individual dwelling* | 10.9 | 24.2 | 20.7 | 25.1 | 28.5 | 32.7 | 30.8 |

Table 8 - IES VE modelled frequency of overheating in different climates

Results show that the differences between the modelled frequencies of overheating for the whole building case and the individual flat case are in general closer together than the PHPP calculation suggests and the range of values from using historic data to data for the year 2080 is also smaller.

Modelling the tower block using IES VE can also offer a more detailed breakdown of regions where overheating is likely as overheating outputs can quickly be given for individual flats/rooms.

The position of the flat within the building envelope is obviously important to its likeliness to overheat. IES calculates data on all the rooms in the building simultaneously so can provide insight into where exactly overheating may occur as well as to what extent. As a dynamic model, the software calculates air temperature at all points within the building so can model the temperature stratification that may occur for flats at different altitudes. Doing a similar analysis in PHPP does not

provide the same level of detail on the temperature distribution within the building, but can approximately account for increased air infiltration at higher altitudes due to higher wind speeds through altering the wind protection coefficient for higher stories, a feature which is not currently included in the IES calculation.

Table 9 shows how the frequency of overheating varies for flats on different stories of the building, showing results from both the IES model and the PHPP model:

| ***Portsmouth Historical*** | ***Percentage overheating in individual flats [%]*** | | | | |
|---|---|---|---|---|---|
| ***Floor*** | **Ground** | **First** | **Second** | **Third** | **Fourth** |
| ***IES VE*** | 1.3 | 7.0 | 10.1 | 10.9 | 10.5 |
| ***PHPP*** | 0.2 | 15.2 | 14.7 | 15.0 | 11.0 |

**Table 9 - Frequency of overheating for flats at different levels of the tower block**

This resolution can be further increased for individual rooms within a flat, for example as shown for the third floor flat, with the results displayed in Table 10:

| *Portsmouth Historical* | *Percentage overheating in individual rooms within flat on third floor [%]* | | | | | |
|---|---|---|---|---|---|---|
| ***Room*** | **Bed 1** | **Bed 2** | **Bed 3** | **Living room** | **Kitchen** | **Bathroom** |
| *Frequency of overheating* | 7.1 | 12.8 | 11.1 | 12.9 | 10.4 | 12.2 |

**Table 10 - Frequency of overheating for individual rooms within third floor flat**

Overheating is more prevalent in upper floor flats which do not benefit from the thermal sheltering provided by the ground, have less local shading from neighbouring buildings and trees and are most at risk from temperature stratification as warm air tends to rise.

High levels of overheating are observed in the living room and in bedroom 2, which could be especially uncomfortable for residents as bedrooms are often designed to be at cooler temperatures to the other living rooms. Health risks are also found to increase with high night time temperatures so it is particularly crucial to address these problems in bedrooms.

The severity of overheating that is predicted to occur is also important to model as temperature spikes allow little time for adjustment and can pose a more serious health risk. Both PHPP and IES allow not only the amount of hours spent above 25$^{o}$C be displayed, but also the proportion of hours at varying temperatures above 25$^{o}$C. This breakdown is shown below in Figure 3 for the historical case and the 2050 a1fi case, using the IES model:

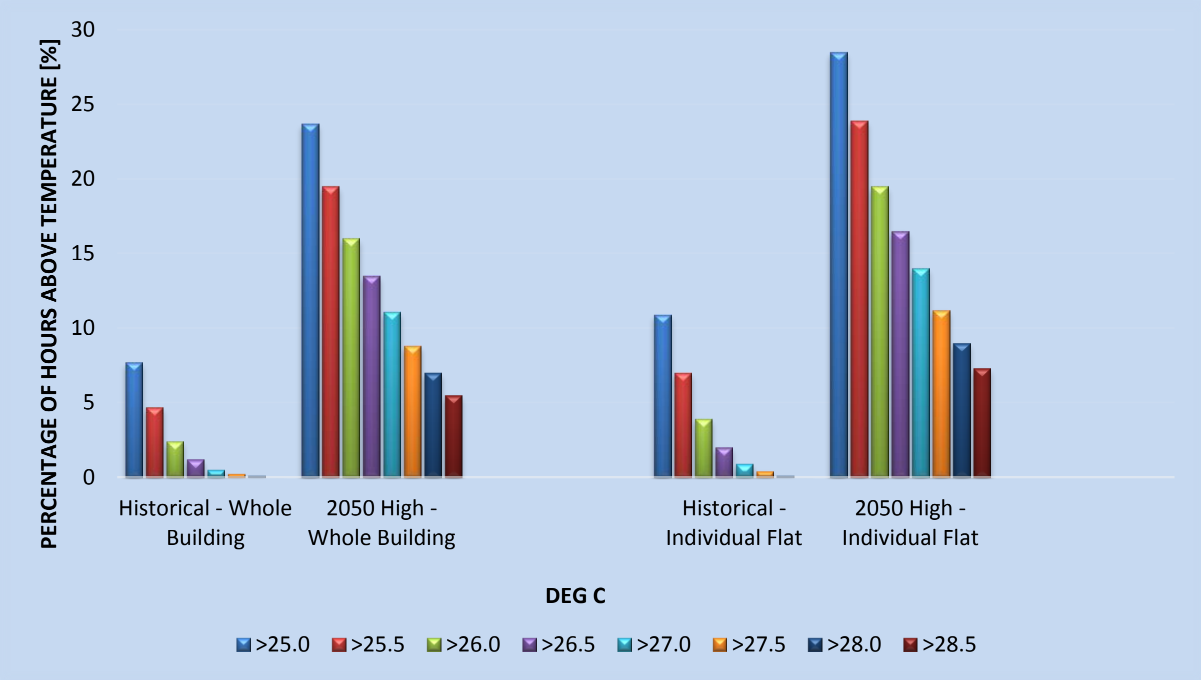


**Figure 3 - Analysis of severity of overheating using historical and future weather data for 2050**

These results highlight a key issue with summer overheating going into the future **whereby the definition of using time spent above 25°C, does not give any indication as to the severity of the overheating that will be experienced**. The methodology for assessing overheating developed by the Chartered Institution of Building Services Engineers (CIBSE)- Technical Memorandum 52 (TM52) - is, in this respect, much more detailed and distinguishes overheating under three separate criteria which include, maximum temperature, time spent over a threshold temperature during summer and a daily measure of the severity of overheating. This methodology also includes different criteria for sensitive residents such as the elderly or the sick and is therefore a more appropriate definition to use than that utilised in the Passivhaus standard.

### *Effectiveness of some simple solutions*

It is clear from the above results that a building of this type will have to make allowances for the prevention of summer overheating going into the future – including increased window opening, shading or even active cooling. Routine maintenance, such as replacement of windows, could give an opportunity to either install shading devices or even replace the glass with low g-value glass to limit overheating.

A similar graph to Figure 3 above is shown below in Table 12, but with increased window opening and external blinds modelled in addition to the baseline specification:

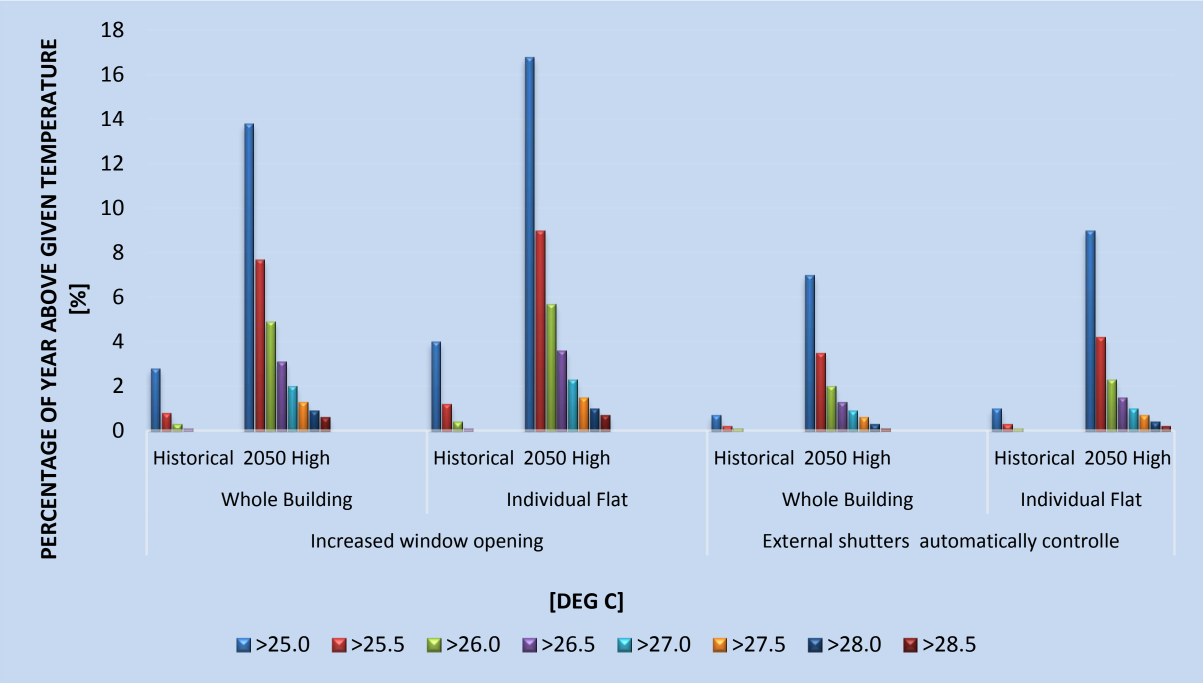


**Table 11 – Analysis of severity of overheating but with additional measures of increased window opening and automatically controlled external blinds modelled for both historical and 2050 weather data.**

The reduction from the baseline using historical data is significant in both cases and reduces the frequency of overheating within a comfortable range, but for the future case, it can be seen that high maximum temperatures are still being reached, particularly when only relying on increased window opening which could pose a serious health risk to residents. This highlights a key point with increased ambient temperatures both during the day and the night, whereby **night time ventilation using cool night air, will become increasingly ineffective as warmer ambient temperatures, and therefore warmer nights, reduce the temperature gradient and cooling effect**. This is particularly important for high thermal mass buildings where night purging of heat is critical to the function of the design.

This result again highlights **the advantage of external shading whereby solar gains are prevented from entering the building in the first place** and therefore reduce both the level and severity of overheating that occurs even going into the future climate.

A wide range of further sensitivity analyses with a number of other software packages can offer more insight into the best way to both model and subsequently design for minimising overheating and further research into this area is both underway and also needed to ensure that an effective methodology for both assessment and modelling can be developed.


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## Conclusions and good practice for preventing overheating

A number of key results can be gathered from this brief analysis:

### *Modelling*

- **Overheating is a complex issue with complexity increased through the lack of a clear definition or measurable quantity –** CIBSE guidance from TM52 should be used for a more detailed definition and assessment procedure when assessing overheating risk
- **Modelling software has its limitations and these must be well understood before making design decisions** – in complex or special use buildings it may be necessary to calculate overheating values for individual rooms; users should ask whether the software includes all the important processes and systems that cause or exacerbate overheating.

### *Design*

- **Increasing ambient temperatures in future climate scenarios suggest that measures to prevent overheating are required in most cases between now and 2050** – preparing new builds or renovations to be able to easily attach shading devices at a later stage (future-proofing) could save on higher installation costs in the future whilst not incurring the unnecessary maintenance costs in the early years (i.e., whilst overheating is still not a problem.)
- **Different strategies can be implemented to reduce the frequency of overheating; however:**
  - **Passive strategies are preferable – no energy is required**
  - **Strategies which require no occupant input are more consistent (fixed objects, automatic controls)**
  - **Window opening (especially at night time) becomes increasingly less effective at cooling the building as external ambient temperatures increase into the future– however it is still a highly effective method of passive cooling**
  - **Modelling shows that external blinds/shutters (preferably with automatic controls) provide effective protection against overheating going into the future**

The priority in building design still remains in optimising energy efficiency in the winter case, but with increased insulation and general energy efficiency requirements being seen in building regulations and specifications, the need for a bi-functional design to address both the summer and winter cases is becoming increasingly necessary. The issues seen in Passivhaus buildings today are likely to become the issues that will be seen in the general housing of the future as the recognition of the benefits of efficient building fabric is brought into the mainstream. These issues, should therefore, be considered carefully in design now in order to protect occupant health and comfort and to remove the need for expensive retrofitting of cooling measures in the future.


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## References & further reading

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5. *Defining Overheating*
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