Bicester Eco-Town,
Oxfordshire

Overheating Analysis and Climate Change Mitigation

PRP

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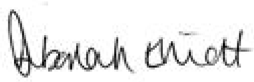
Signature		

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1 INTRODUCTION

PRP Environmental has been commissioned by A2 Dominion Housing Group to carry out an overheating analysis on the selected units 265, 288 and 281 within Phase 2 of Bicester Ecotown, Oxfordshire development.

One of the key aims of this study is to investigate the impact of climate change on Bicester and examine any potential risk of summer overheating that the buildings on Phase 2 may suffer from today and in the future. It is therefore a primary scope of this report to assess summer overheating risks for the current weather scenario and three more future weather projections (2030, 2040 and 2050), according to the requirements of planning condition 10.

The analysis was undertaken using the new parameters and guidelines by CIBSE TM52:2013 'The limits of thermal comfort: avoiding overheating in European buildings', which replaces the guidelines defined under Guide A 'Environmental Design'. The new guide by CIBSE explains a series of criteria by which the risk of overheating can be identified and assessed. A room or building that fails any two of the three criteria is classed as overheating (see Appendix 2).

Three sample dwelling types (two private and one affordable) deemed to be representative of worst case scenarios within the new development, were modelled to assess their overheating risk. In addition, this assessment aims to identify how the changes proposed in the earlier stages of the design affect the internal temperatures up to 2050. The analysis highlights the most effective mitigation measures of the design that might affect the internal operative temperatures during occupancy hours and provide measures, which could be implemented to mitigate any risk of overheating.

The current analysis is focused on three units within Phase 2 of Bicester Eco Town that were considered as worst-case scenarios:

- **Private House 265** - 3 bedrooms
- **Private House 281**- 3 bedrooms
- **Affordable Bungalow 288** - 3 bedrooms

The location and layout are illustrated in Figures 1 to 4 below.

The following options have been tested for each unit using a number of assumptions:

Base case: Triple glazing windows (U=0.83) along with a solar transmittance of 0.27 (g-value) and a natural ventilation during occupancy hours

- Option 1: Assign internal blinds to all of the windows
- Option 2: Utilise night time cooling on the first floor areas only
- Option 3: Combine blinds with night time cooling
- Option 4: For Plot 281 only, assign spandrel panel to parts of the bay window

- Option 5: For Plot 281 only, assign overhang on the south and west side of the bay window.

It is important to note that with any modelling exercise there are assumptions and approximations that have to be made. As far as possible, details of all assumptions and approximations used are supplied as part of this report. These should be read carefully to gain an understanding of the parameters of the modelling.

All results are based on the output from computer modelling software and should be taken as an indication of the likely final situation, but these conditions cannot be guaranteed in real world situations.

1 METHODOLOGY AND OVERHEATING CRITERIA

Criteria

This study assesses summer overheating risks for the current weather scenario and three more future weather projections across consecutive decades (2030, 2040 and 2050).

For this analysis, the methodology was based on the new criteria set out by CIBSE TM 52: 2013 'The limits of thermal comfort: avoiding overheating in European buildings' that will gradually supersede CIBSE Guide A 2006 Methodology for overheating analysis (Appendix 2).

The following guidelines define overheating in free-running buildings according to TM52 (Appendix 2):

The first criterion sets a limit for the frequency of over-heating, by measuring the number of hours that the operative temperature can exceed the threshold comfort temperature by 1K or more during the occupied hours of a typical non-heating season (1 May to 30 September)

The second criterion deals with the severity of overheating within any one day, which can be as important as its frequency, the level of which is a function of both temperature rise and its duration. This criterion sets a daily limit for acceptability.

The third criterion sets an absolute maximum daily temperature for a room, beyond which the level of overheating is unacceptable.

These criteria represent the latest guidance from CIBSE and provide a robust and balanced control of the risk of overheating and in order for a room to be classified as compliant then it will need to meet at least two out of the three criteria:

The three overheating criteria set out by CIBSE TM52 are described in more detail below:

Criteria 1: Hours of Exceedance (He)

The number of hours (He) during which ΔT, which is the difference between the actual operative temperature in the room at any time (Top) and Tmax the limiting maximum acceptable temperature, calculated is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3 per cent of occupied hours.

$\Delta T = Top - Tmax$

Criterion 2: Daily Weighted Exceedance (We)

The second criterion deals with the severity of overheating within any one day, which can be as important as its frequency, the level of which is a function of both temperature rise and its duration. This criterion sets a daily limit for acceptability, which should be less than or equal to 6 in any one day.

Criterion 3: Upper limit temperature (Tupp)

The third criterion sets an absolute maximum daily temperature for a room, beyond which the level of overheating is unacceptable.

To set an absolute maximum value for the indoor operative temperature the value of ΔT, which is the difference between the actual operative temperature in the room at any time (Top) and Tmax the limiting maximum acceptable temperature, shall not exceed 4 K.

It has been assumed that the analysed buildings fall under the Category II of CIBSE recommendations (table 1).

Table 1. CIBSE suggested applicability of the categories and their associated acceptable temperature range for free-running buildings and of Predicted Mean Vote for mechanically ventilated buildings

Category	Explanation	Suggested acceptable range (K)	Suggested acceptable limits PMV
I	High Level of expectation only used for spaces occupied by very sensitive	± 2	± 0.2
II	**Normal expectation (for new buildings and renovations)**	**± 3**	**± 0.5**
III	A moderate expectation	± 4	± 0.7
IV	Values outside the criteria for the above categories (only acceptable for a limited period)	> 4	> 0.7

2 ANALYSIS

2.1 Geometry, Location and Zone Layouts

The site is located on the edge of Bicester, Oxfordshire. Figure 1 below shows the location of the site within the Phase 2 boundary. This image also shows the surrounding buildings to the site, as they were considered to be obstructions that shaded the selected units.

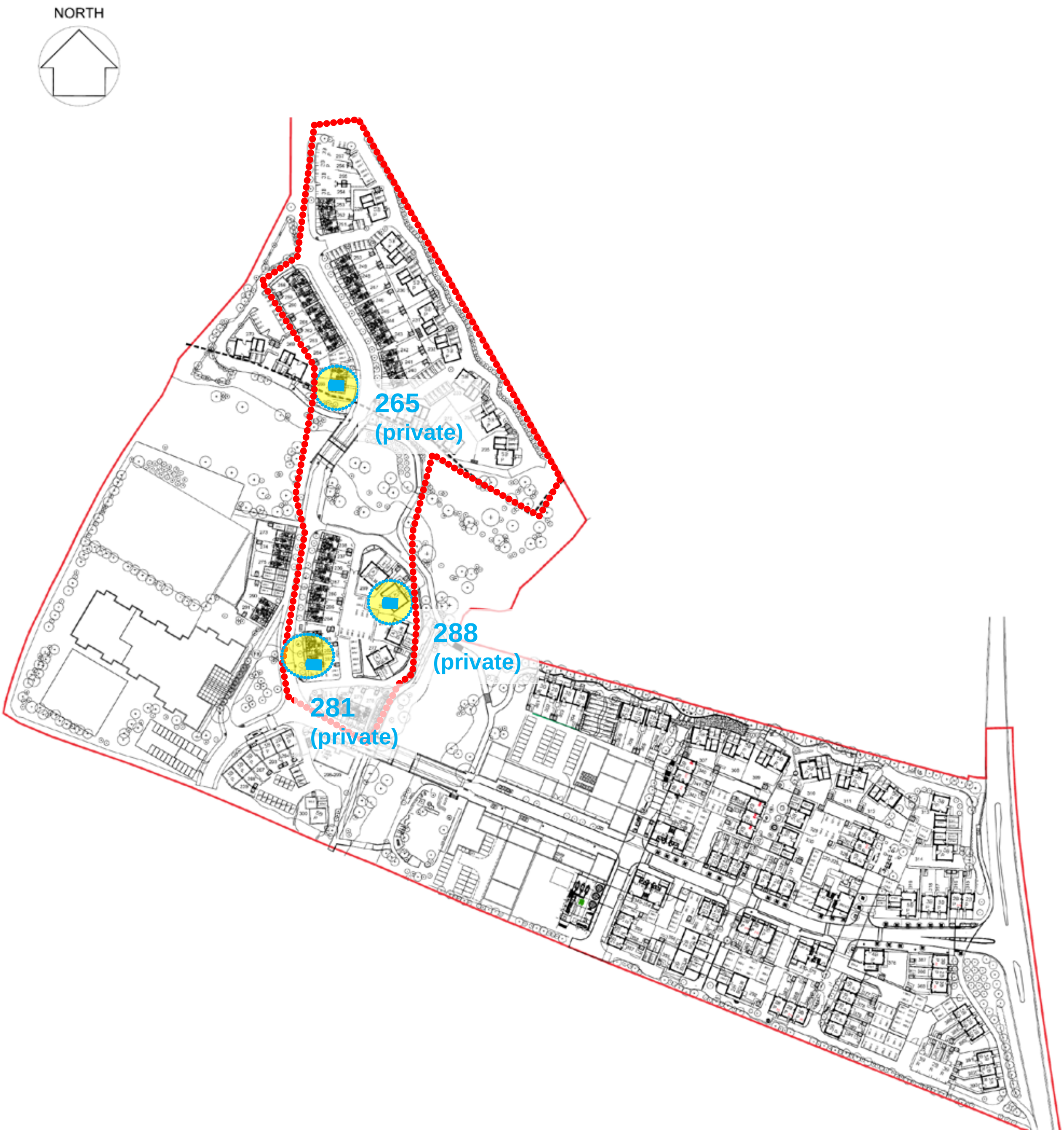


Figure 1. Location of units 288, 281 and 265 assessed in Phase 2 of Bicester Ecotown

2.2 Methodology

The methodology used for this analysis followed an initial desktop assessment that determined the worst-case scenario units of each type in Phase 2 of Bicester Ecotown development. The selection criteria were based on the following:

- Orientation – South and West facing dwellings will suffer from the high altitude mid afternoon solar radiation
- Shading by the surroundings elements – Dwellings that are not sheltered have been selected, as they will have higher solar heat gains
- Exposed walls – dwellings with more exposed walls will have high solar heat gains conducted through the building envelope into the dwelling
- Less Heat loses.

The key dwelling types and variations were analysed initially in SAP (2009):

- Plot 230: 5-Bedroom house-private
- Plot 231: 5- Bedroom house- private
- Plot 240: 3-Bedroom house-private
- Plot 265: 3-Bedroom house-private
- Plot 288: 3-Bedroom bungalow-affordable
- Plot 300: 4-Bedroom house-private
- Plot 281: 3-Bedroom house- private

The selected units were assessed in NHER Plan assessor software version 5.4.1, which uses the SAP (2009) (Standard Assessment Procedure) methodology, to test their compliance with Part L1A (2010) Criterion 3-Summer overheating risk[2].

Seven dwellings have been modelled under five different scenarios, using the current weather data, to assess their potential summer overheating risk. The five different scenarios modelled are:

- Scenario 1: All windows are assumed fully open half the time
- Scenario 2: All windows are assumed slightly open; i.e. 50mm open
- Scenario 3-Mechanical ventilation system with an air change rate of 2ach
- Scenario 4-Mechanical ventilation system with an increased air change rate of 2.5 ach
- Scenario 5-Threshold air change rate required to overcome the overheating risk

The SAP assessments undertaken have clearly demonstrated that the assessed dwellings have shown some risk of overheating in some of the scenarios listed above using the current weather scenario.

Table 2. Results of SAP calculations regarding the overheating risk for the different Plots and different scenarios:

Plot	230 5B detached			231 5B detached			233 (230 handed) 5B detached			240 3B ET private?		
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug
Windows fully open half the time	N	S	S	N	S	S	N	S	S	N	S	S
Windows slightly open	S	H	H	S	M	M	S	H	H	M	H	H
Air change rate 2	N	M	S				N	M	S	N	M	M
Air change rate 2.5	N	S	S				N	S	S	N	M	M
Air change rate threshold for overheating	1.2						1.1			1.6		

[2] NB Criterion 3 – Reasonable provision to limit heat gains in properties is a criterion used ot deonstrate compliance with Part L and should not be confused with Dynamic Simulation which is a design tool.

Plot	265 3B ET private			288 3B bungalow afford			300 4B house private			281 3B house private		
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug
Windows fully open half the time	N	S	S	N	N	S	N	S	S	N	S	S
Windows slightly open	M	H	H	M	H	H	M	H	H	M	H	H
Air change rate 2	S	M	M	N	M	M	S	M	M	S	M	M
Air change rate 2.5	N	M	M	N	M	M	N	M	M	N	M	M
Air change rate threshold for overheating	1.7			1.5			1.8			1.7		

OVERHEATNG RISK	
H	High
M	Medium
S	Slight
N	None

As a result of the SAPs calculations the worst performing units are the following:

- Plot 265
- Plot 288
- Plot 300
- Plot 281

Dynamic Modelling

Dynamic thermal analysis has been performed only on the selected units 265, 281 and 288, that were considered the most representative-and repetitive across the site, in order to assess the resulting conditions during the course of a design year. The analysis accounts for the characteristics of each space (living rooms & bedrooms) including the internal gains, building fabric details, building orientation and external weather conditions.

The thermal model of the proposed development was constructed using Integrated Environmental Solutions (IES-VE) version 7.0.1.0, which complies with CIBSE Applications Guide AM11 'Building Energy and Environmental Modelling'

For the current weather year analysis, the Design Summer Years (DSY) weather data for the London area, which is based on an urban environment, has been used.

The Low Carbon Building Group of Oxford Brookes University provided the projected weather year's data, which has been being used in this analysis for future risks of overheating. The report "Future Climate changes projections for NW Bicester" explains how these climate projections were calculated.

These future weather scenarios were tested to comply with the climate change adaptation requirements of the Planning Policy Statement for eco-towns (PPS1), which states the following:

"ET 8.1 Eco-towns should be sustainable communities that are resilient to and appropriate for the climate change now accepted as inevitable. They should be planned to minimise future vulnerability in a changing climate, and with both mitigation and adaptation in mind.

ET 8.2 Developments should be designed to take account of the climate they are likely to experience, using, for example, the most recent climate change scenarios available from the UK Climate Change Impacts Programme. Eco-towns should deliver a high quality local environment and meet the standards on water, flooding, green infrastructure and biodiversity set out in this PPS, taking into account a changing climate for these, as well incorporating wider best practice on tackling overheating and impacts of a changing climate for the natural and built environment."

Internal heat gains from occupants, lighting, electrical and cooking equipment as well as the range of activities that take place in habitable rooms were included within the simulation as they have a significant impact on the internal temperatures and were modelled against occupancy patterns.

The assumptions described in the following section have been made according to the occupancy patterns, electrical lighting, electrical equipment, cooking, ventilation strategy and the building fabric specification.

2.2.1 UNIT 288 - Affordable-Bungalow

Figure 2 below shows plans of the house 288 that was modelled in IES software. The orientation and immediate surrounding buildings were also included within the 3D model to account for any shading that may result from those buildings.

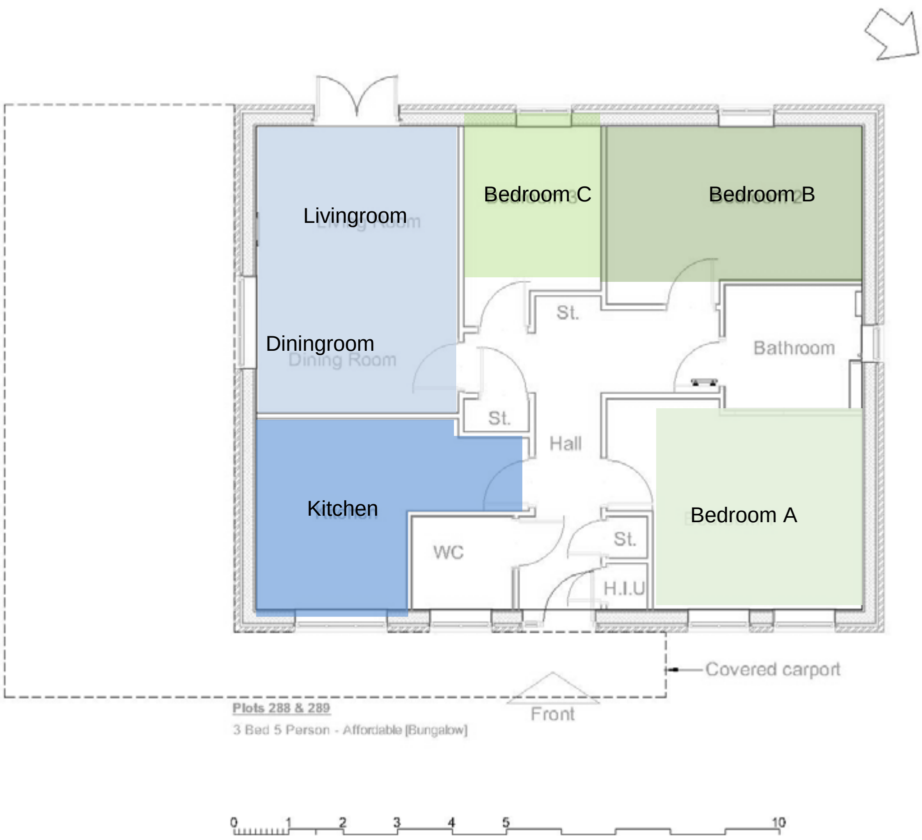


Figure 2. Floor plans of house 288. Rooms analysed are highlighted

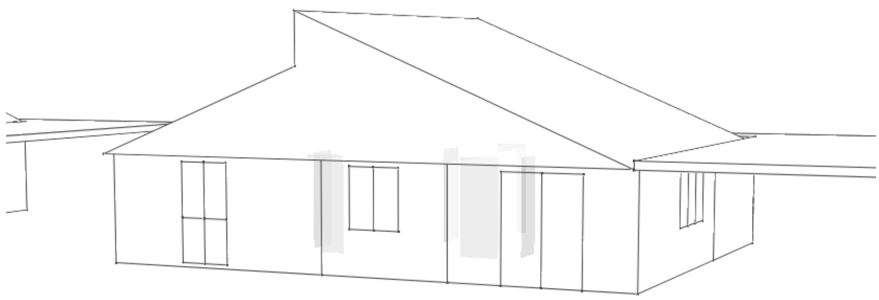


Figure 3. Unit 288. 3D View

2.2.2 UNIT 281 - Private Unit

House type 281 is a private house and its plan and layout are shown in the following image *(ground and first floor*:

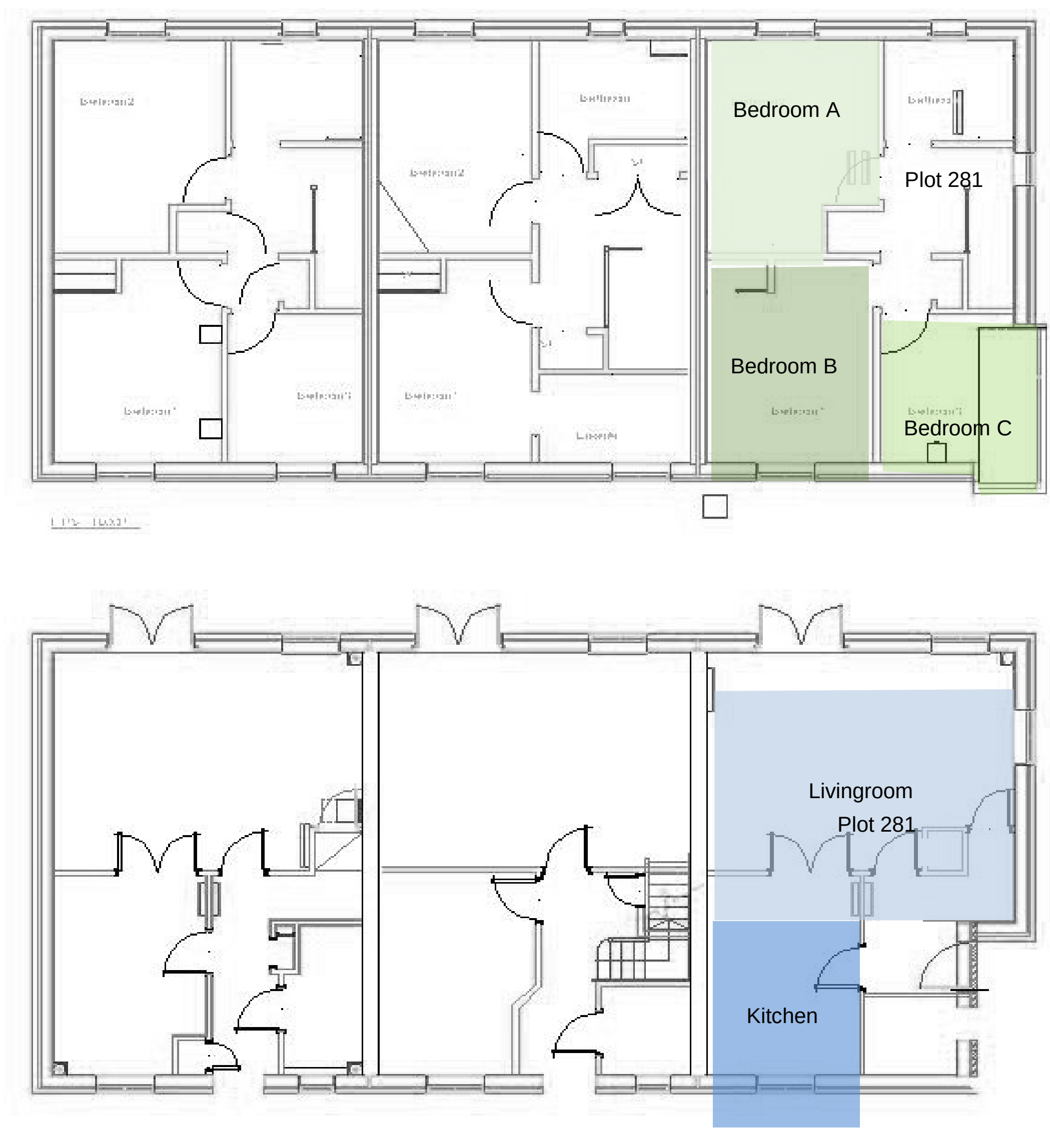
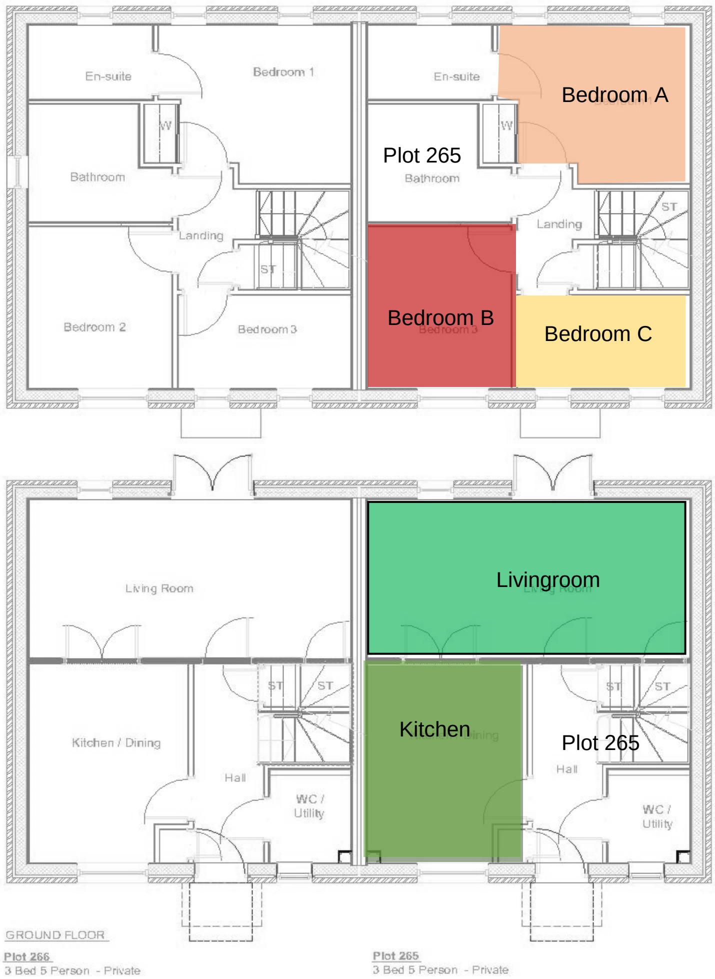


Figure 4. Floor plans of house 281. Rooms analysed are highlighted

2.2.3 UNIT 266 - Private Unit

Similarly, house type 266, is a private unit and was modelled based on its orientation and surrounding environment (Figure 5).



Ground and first floor

Figure 5. Floor plans of houses 265 and 266. Rooms analysed are highlighted

2.3 Building Elements

The following building elements were used for the base case model.

Table 3. Building elements. Base Case

Building Elements		Construction / Materials	U-value W/m² °C
WALLS	External	Timber frame superstructure with 103mm facing brickwork to outer leaf	0.15
	Internal	• Plasterboard • Timber Studwork • Plasterboard	-
	Ground	• Vinyl finish • Insulation (50mm) • Flooring screed • EPS Insulated Block flooring system (90mm) • Brick slips	0.15
	Intermediate floor / Slabs	• C5 moisture resistant chipboard • open metal web floor joists • Fireline plasterboard	-
ROOF	Roof / ceiling	• Plasterboard • Fully insulated OSB • softwood saturated bitumen felt • treated sw battens • Unventilated cavity • PV solar panels	0.13
OPENINGS	Windows	• Triple glazing (6mm) • 16mm Argon filled cavity	0.80 G-value= 0.27
	Main Door	• Softwood • Insulation • Plywood	1.1
	Internal doors	• Wood	2.30

2.4 Internal Gains

Occupancy, lighting and equipment gains were initially based on NCM (National Calculation Methodology) for domestic properties using data supplied by the design team.

Table 4. Internal gains

Space	Thermal Conditions	Lighting Gain (W/m²)	Occupancy gains (W/person)		Equipment gains (W/m²)	
			Sensible	Latent	Sensible	Latent
Dining/ Kitchen	Dwell_DomDining_v3.5	7.8	60	60	5.0	0.0
Living rooms	Dwell_DomLounge_v3.5	7.8	1.34	0.86	5.0	0.0
Bathroom	Dwell_DomBath_v 3.5	7.8	60	60	1.67	0
Bedroom	Dwell_DomBed_v 3.5	5.2	67.50(single) 2.7(double)	22.50 (single) 1(double)	2.90	0.68
SCHEDULE USED		Lighting &Equipment: **5-9am & 7-11pm**	Profile Selected is **MEDIUM HIGH (0-9am & 5-0pm)**		Lighting &Equipment: **5-9am & 7-11pm** with setback of 0.01 W/m²	

2.5 Ventilation

Natural ventilation is possible via openable windows and doors.

Table 5. Aperture schedule and profile

APERTURES	Room	Profile	
		Starts opening when adjacent zone at:	Fully opened adjacent zone at:
Windows	Living area (90% openable)	19ºC	22ºC
	Wetrooms (90% openable)	19ºC	22ºC
	Other Rooms (90% openable)	19ºC	22ºC
	Night Cooling (When Applicable)	Open 95% of the window while Night-time (6pm-8am) **NOTE: During Occupied hrs**	
Due to the security reasons, all the windows on the Ground floor can be only opened during occupied hours and are completely closed at night.			
Doors	Main	Opened 10min of occupied hours, equivalent to 1%	
	Internal	100% opened whole day time and 10% during night	

It has been assumed that the occupants will open their windows when the internal temperatures exceed 19ºC to 22°C (see table above). Occupants will have full control of their window opening system and can manually open these when they experience warm temperatures inside. There is no intention to install automatic openable systems.

In order to maximise natural ventilation within the dwelling during the summer period, background ventilation using trickle vents in all of the windows were assigned on the private units (281 and 265) and extract ventilation will be installed within the kitchen and bathroom areas. For the affordable unit 288, a balanced system that does not require background ventilation, using Mechanical ventilation with Heat Recovery (MVHR) has been considered.

2.6 Infiltration

An air infiltration rate of 0.155ACH, which is equivalent to air tightness of 3.0m^3/hr/m^2@50Pa, has been assumed in this analysis.

2.7 Weather data

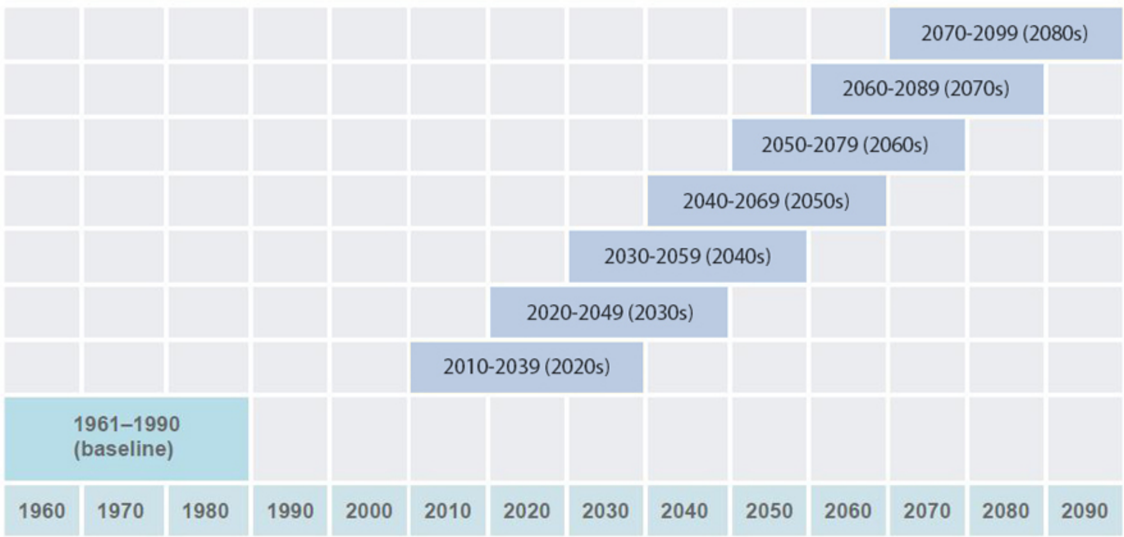
- **Current weather year file:** CIBSE *London DSY* (Design Summer Year) weather data, which is 2005.

- **Projected weather files.** MEDIUM Emissions Scenario; these files were provided by Oxford Brooks University

UK_WM_Oxford_2030_a1b_90Percentil; where a1b corresponds to a medium emissions scenario and 90 percentile refers to the probability of the climate change impact occurring.

UK_WM_Oxford_2050_a1b_90Percentil: where a1b corresponds to a medium emissions scenario and 90 percentile refers to the probability of the climate hcnage impact occurring.

The following figure outlines the concept of 7 overlapping time-slices, each representative of 30 years. This is a standard for climate studies performed by academia as well as the industry, in line with the information presented in the 2009 UK Climate Projections (UKCP09). The middle decade of each time slice is used as an abbreviation, i.e. 2020s indicate the period covering 2010 to 2039.



2.8 Occupancy Profiles

MEDIUM HIGH Occupancy has been assumed as it represents a realistic scenario for the daily occupancy of the house:

- **Weekdays:** *Working Hours (4pm to 9am)*

- **Weekends:** *24 hours*

3 3. ITERATIONS

A number of iterations have been tested for each of the climatic data, first being a solar shading device (internal blinds) and the second being a purge mechanism through (night time) ventilation. Both measures have been tested in combination, in order to evaluate the optimum mitigation scenario for all of the houses. Plot 281 has been tested further with different design alterations for each of the climatic data due to higher risks identified.

3.1 Single

- **Solar Shading (Blinds)**

Solar shading, in the form of temporary blinds, has been incorporated into all of the windows in the unit. The window blinds are assumed to be closed from 9am to 6pm to protect the internal spaces from solar gains.

- **Night Cooling (NC)**

The model was re-run with windows opened only on the first floor, during night time (7pm to 9am). This allows the building fabric to cool as external temperatures drop allowing heat gains absorbed during the day to be naturally removed from the internal spaces. This measure does not require any additional cost or material production, while at the same time is bringing a significant reduction in overheating hours. Due to security reasons, this measure is applicable only to first floor windows. Ground floor windows can be opened only during occupied hours and kept closed during night time and therefore this iteration is not relevant to the bungalow (plot 288) tested.

According to the simulation results (Appendix 4) each of the above iterations are predicted to reduce overheating hours and improve thermal comfort within the living areas. However, in order to demonstrate achievement of lower internal temperatures and achieve CIBSE TM52 compliance, combined iterations have also been modelled.

3.2 Combined

- **Combining Night Cooling (NC) and Solar Shading (Blinds)**

This iteration combines night time cooling, opening first floor windows from 7pm to 9am and closing internal blinds during the day when solar gains are higher. In this way, solar gains are prevented during the day and the excess heat is released over night. This combination is considered the most effective measure as both variables are applied.

3.3 Plot 281 only: Added spandrel panel

Due to increased internal temperatures, further iterations have been modelled for Plot 281 alone, in order to mitigate any excess heat concentrated in the internal area of the bay window, where bedroom C is located (Figure 4). A spandrel panel will replace parts of the bay window, minimising the glazing area of the space and retaining the initial architectural concept. All the previous measures have been considered and modelled accordingly.

Figure 6. 3D image of Plot 281with the spandrel panel

3.4 Plot 281 only: Added Overhang

Similarly, an overhang has been assumed, as a design iteration, over the south and west side of the bay window in Plot 281.

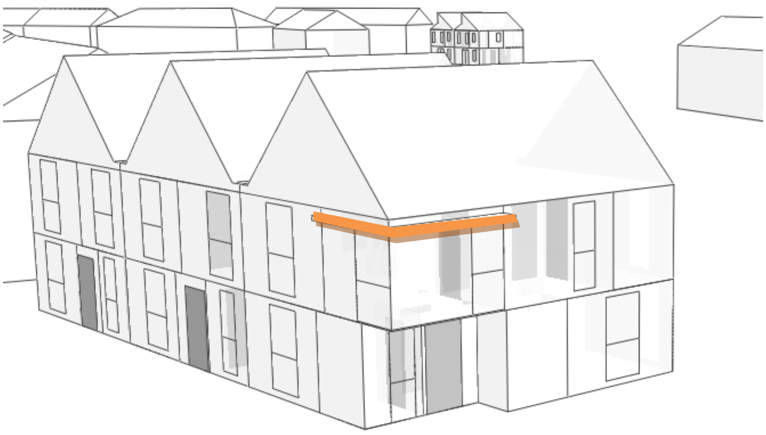


Figure 7. 3D image of Plot 281with the overhang added on the bay window

4 RESULTS AND DISCUSSIONS

The tables below show the results for each year analysed. Future projections are for Medium Emissions 90 percentile scenario. The risk ranking provided in the following tables documents the outcome of the overheating assessment, performed against CIBSE TM52 three criteria (discussed in Appendix 2), indicating:

- No Risk, for rooms passing all of the three criteria
- Minor Risk, for rooms failing only one of the three criteria
- Risk, for rooms failing any two of the three criteria (thus overheating, according to the the CIBSE TM52)

The results are presented in more detail in Appendix 4:

4.1 Current DSY 2005

CURRENT DSY (2005)-Summary of criteria- TM52					
MEDIUM HIGH Week Work Hrs (4pm-9am) & Wknd 24hr	**All Plots**	**Single Iterations**			**Combined iterations**
	Plot 265	**Base case**	**Blinds**	**NC**	**NC+shutter**
	PL265_GF_Kitchen	NO RISK	NO RISK	NO RISK	NO RISK
	PL265_GF_Living	NO RISK	NO RISK	NO RISK	NO RISK
	PL265_1stFL_BedAx2	MINOR RISK	NO RISK	NO RISK	NO RISK
	PL265_1stFL_BedBx2	MINOR RISK	NO RISK	NO RISK	NO RISK
	PL265_1stFL_BedCx1	MINOR RISK	NO RISK	NO RISK	NO RISK
	Plot 281				
	PL281_GF_Kitchen	MINOR RISK	MINOR RISK	NO RISK	NO RISK
	PL281_GF_Living	NO RISK	NO RISK	NO RISK	NO RISK
	PL281_1stFL_BedAx2	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL281_1stFL_BedBx2	NO RISK	MINOR RISK	MINOR RISK	NO RISK
	PL281_1stFL_BedCx2	RISK	RISK	RISK	MINOR RISK
	Plot 288				
	PL288_Kitchen	NO RISK	NO RISK	NO RISK	NO RISK
	PL288_Living/Dining	NO RISK	NO RISK	NO RISK	NO RISK
	PL288_BedAx2	NO RISK	NO RISK	NO RISK	NO RISK
	PL288_BedBx2	NO RISK	NO RISK	NO RISK	NO RISK
	PL288_BedCx1	NO RISK	NO RISK	NO RISK	NO RISK

4.2 Projection 2030 Medium Emissions

FUTURE DSY (2030)-Summary of criteria- TM52					
MEDIUM HIGH Week Work Hrs (4pm-9am) & Wknd 24hr	**All Plots**	**Single Iterations**			**Combined iterations**
	Plot 265	**Base case**	**Blinds**	**NC**	**NC+shutter**
	PL265_GF_Kitchen	NO RISK	NO RISK	NO RISK	NO RISK
	PL265_GF_Living	NO RISK	NO RISK	MINOR RISK	NO RISK
	PL265_1stFL_BedAx2	NO RISK	NO RISK	NO RISK	NO RISK
	PL265_1stFL_BedBx2	NO RISK	NO RISK	NO RISK	NO RISK
	PL265_1stFL_BedCx1	NO RISK	NO RISK	NO RISK	NO RISK
	Plot 281				
	PL281_GF_Kitchen	MINOR RISK	NO RISK	MINOR RISK	NO RISK
	PL281_GF_Living	MINOR RISK	NO RISK	MINOR RISK	NO RISK

	PL281_1stFL_BedAx2	MINOR RISK	MINOR RISK	RISK	NO RISK
	PL281_1stFL_BedBx2	MINOR RISK	MINOR RISK	MINOR RISK	NO RISK
	PL281_1stFL_BedCx2	RISK	RISK	RISK	RISK
	Plot 288				
	PL288_Kitchen	NO RISK	NO RISK	NO RISK	NO RISK
	PL288_Living/Dining	NO RISK	NO RISK	MINOR RISK	NO RISK
	PL288_BedAx2	NO RISK	NO RISK	MINOR RISK	NO RISK
	PL288_BedBx2	NO RISK	NO RISK	MINOR RISK	NO RISK
	PL288_BedCx1	NO RISK	NO RISK	MINOR RISK	NO RISK

4.3 Projection 2050 Medium Emissions

FUTURE DSY (2050)-Summary of criteria- TM52					
MEDIUM HIGH Week Work Hrs (4pm-9am) & Wknd 24hr	Plots	**Single Iterations**			**Combined iterations**
	Plot 265	**Base case**	**Blinds**	**NC**	**NC+shutter**
	PL265_GF_Kitchen	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL265_GF_Living	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL265_1stFL_BedAx2	MINOR RISK	MINOR RISK	NO RISK	NO RISK
	PL265_1stFL_BedBx2	MINOR RISK	MINOR RISK	NO RISK	NO RISK
	PL265_1stFL_BedCx1	MINOR RISK	NO RISK	NO RISK	NO RISK
	Plot 281				
	PL281_GF_Kitchen	MINOR RISK	RISK	MINOR RISK	MINOR RISK
	PL281_GF_Living	RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL281_1stFL_BedAx2	RISK	RISK	RISK	MINOR RISK
	PL281_1stFL_BedBx2	RISK	RISK	MINOR RISK	MINOR RISK
	PL281_1stFL_BedCx2	RISK	RISK	RISK	RISK
	Plot 288				
	PL288_Kitchen	MINOR RISK	MINOR RISK	RISK	MINOR RISK
	PL288_Living/Dining	RISK	NO RISK	MINOR RISK	NO RISK
	PL288_BedAx2	MINOR RISK	NO RISK	MINOR RISK	NO RISK
	PL288_BedBx2	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL288_BedCx1	MINOR RISK	NO RISK	MINOR RISK	NO RISK

4.4 Current DSY 2005 - Design alterations in Plot 281

CURRENT DSY (2005)-Summary of criteria- TM52					
MEDIUM HIGH Week Work Hrs (4pm-9am) & Wknd 24hr	Plot 281	**Single Iterations**			**Combined iterations**
	Spandrel panel	**Base case**	**Blinds**	**NC**	**NC+shutter**
	PL281_GF_Kitchen	MINOR RISK	MINOR RISK	MINOR RISK	NO RISK
	PL281_GF_Living	NO RISK	NO RISK	NO RISK	NO RISK
	PL281_1stFL_BedAx2	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL281_1stFL_BedBx2	MINOR RISK	MINOR RISK	NO RISK	NO RISK
	PL281_1stFL_BedCx2	RISK	MINOR RISK	RISK	MINOR RISK
	Overhang				
	#PL281_GF_Kitchen	MINOR RISK	MINOR RISK	MINOR RISK	NO RISK
	#PL281_GF_Living	NO RISK	NO RISK	NO RISK	NO RISK
	#PL281_1stFL_BedAx2	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	#PL281_1stFL_BedBx2	MINOR RISK	MINOR RISK	MINOR RISK	NO RISK

	#PL281_1stFL_BedCx2	RISK	MINOR RISK	RISK	MINOR RISK

4.5 Projection 2030 Medium Emissions- Design alterations in Plot 281

FUTURE DSY (2030)-Summary of criteria- TM52					
MEDIUM HIGH Week Work Hrs (4pm-9am) & Wknd 24hr	Plot 281	**Single Iterations**			**Combined iterations**
	Spandrel panel	**Base case**	**Blinds**	**NC**	**NC+shutter**
	PL281_GF_Kitchen	NO RISK	NO RISK	NO RISK	NO RISK
	PL281_GF_Living	NO RISK	NO RISK	NO RISK	NO RISK
	PL281_1stFL_BedAx2	MINOR RISK	MINOR RISK	MINOR RISK	NO RISK
	PL281_1stFL_BedBx2	MINOR RISK	NO RISK	NO RISK	NO RISK
	PL281_1stFL_BedCx2	RISK	RISK	RISK	MINOR RISK
	Overhang				
	#PL281_GF_Kitchen	NO RISK	NO RISK	NO RISK	NO RISK
	#PL281_GF_Living	NO RISK	NO RISK	NO RISK	NO RISK
	#PL281_1stFL_BedAx2	MINOR RISK	MINOR RISK	MINOR RISK	NO RISK
	#PL281_1stFL_BedBx2	MINOR RISK	NO RISK	NO RISK	NO RISK
	#PL281_1stFL_BedCx2	RISK	RISK	RISK	MINOR RISK

4.6 Projection 2050 Medium Emissions- Design alterations in Plot 281

FUTURE DSY (2050)-Summary of criteria- TM52					
MEDIUM HIGH Week Work Hrs (4pm-9am) & Wknd 24hr	Plot 281	**Single Iterations**			**Combined iterations**
	Spandrel panel	**Base case**	**Blinds**	**NC**	**NC+shutter**
	PL281_GF_Kitchen	RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL281_GF_Living	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	PL281_1stFL_BedAx2	RISK	RISK	MINOR RISK	MINOR RISK
	PL281_1stFL_BedBx2	RISK	RISK	MINOR RISK	NO RISK
	PL281_1stFL_BedCx2	RISK	RISK	RISK	MINOR RISK
	Overhang				
	#PL281_GF_Kitchen	RISK	RISK	MINOR RISK	MINOR RISK
	#PL281_GF_Living	MINOR RISK	MINOR RISK	MINOR RISK	MINOR RISK
	#PL281_1stFL_BedAx2	RISK	RISK	MINOR RISK	MINOR RISK
	#PL281_1stFL_BedBx2	RISK	RISK	MINOR RISK	NO RISK
	#PL281_1stFL_BedCx2	RISK	RISK	RISK	MINOR RISK

5 CONCLUSIONS

PRP Environmental was commissioned by A2 Dominion Housing Group to carry out an overheating analysis on three worst performing units, two private unit (265 and 281) and one affordable (288) within Phase 2 of Bicester Ecotown, Oxfordshire development. In addition, this study identifies a method of mitigating excessive internal temperatures based on industry guidelines defined under CIBSE TM52:2013 'The limits of thermal comfort: avoiding overheating in European buildings', which replaces the guidelines defined under Guide A 'Environmental Design'.

Given the fact that the climate is changing to a warmer one, one of the key aims of this study is to investigate the impact of climate change on Bicester and examine any potential risk of summer overheating that the buildings on Phase 2 may suffer from in the future. It is therefore a primary scope of this report to assess summer overheating risks for the current weather scenario and three more future weather projections (2030, 2040 and 2050).

The primary scope of this report is to identify any risk of overheating and propose a number of mitigation measures for the current and future climatic data. Any overheating post this period will be the responsibility of the homeowners.

The houses within Phase 2 of the Bicester Ecotown development have adopted the design advice in terms of fabric efficiency and energy saving measures early in their inception. However, since the houses have a natural ventilation strategy (with the exception of the affordable unit-288 that has MVHR), it is likely that they will face a risk of overheating, especially when assessed under future weather data (2030-2050).

The current analysis is focused on three units within Phase 2 of Bicester Eco Town, that were considered the worst performing:

- **Private House 265** - 3 bedrooms
- **Private House 281**- 3 bedrooms
- **Affordable Bungalow 288** - 3 bedrooms

Overall, according to the results presented in the previous Chapter (4) the main risk of overheating is primarily identified within the bedrooms of Plot 281. More specifically, Plot 265 is passing all three criteria of CIBSE TM52, even when assessed under the future climatic conditions of 2050. Furthermore, Plot 288 is above the three criteria when assessed under the current weather data, however, under future scenarios there is a minor risk of overheating in the kitchen and living room area. Both can be mitigated when all measures are applied (except night time cooling which is not applicable on ground floors).

The bedroom in plot 281 has been dealt with in more detail due to its south facing bay window. The exposed area of the glazing along with the exposed floor area of bedroom C makes the unit vulnerable to increased temperatures during the summer period. All scenarios for this space are showing a high risk of overheating, which increases into the future. Two further scenarios have been introduced that affect the initial design of the house. The first option is to use spandrel panels in parts of the glazed window and the second to introduce an overhang on its south and west side. Both options are able to decrease the risk of overheating in current weather conditions. The risk, however, is still present for the future conditions. Introducing blinds or night time cooling reduces the risk in two out of three bedrooms and a combination of the two is able to combat overheating in the area of the bay window.

The analysis undertaken indicates a general marginal overheating risk within the living rooms and kitchen areas when assessed under the future weather of year 2050. This risk is anticipated since night time cooling is not feasible within the ground floor areas, unless secure night time ventilation systems can be designed into the units. Although it is not unreasonable to assume lighting and equipment will become more energy efficient and therefore the gains, which contribute to the increase of the internal temperature, will be reduced, these cannot be relied upon to wholly mitigate risks of overheating.

It should also be noted that in order to be consistent with the existing overheating analysis of Phase 1, the current report is based on the National Calculation Methodology (NCM for dwellings) and any deviation from this methodology to demonstrate compliance with different requirements will have an influence on the overheating results.

By adopting the mitigation measures identified for the units tested, the thermal performance of the areas can be maintained at acceptable levels as assessed against the CIBSE TM52 guidelines.

6 REFERENCES

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Appendix 1 Glossary

1	Thermal Comfort and Operative Temperatures	The provision of thermal comfort for building occupants involves designing the internal conditions so that the heat loss and heat gain from occupants lie within the bounds that are generally accepted as comfortable. Thermal comfort is defined in the ISO 7730 as "That condition of mind which expresses satisfaction with the thermal environment". This is a definition most people can agree on but also a definition that is not easily converted into physical parameters. The human body can be crudely regarded as a heat engine that converts fuel (food) into energy for its function and creates waste heat that must be dissipated by the body to ensure proper "thermoregulation". The greater the amount of activity, the greater the amount of heat to be dissipated. Typical office work generates up to 110-130W of heat. Heat dissipation from the body takes place by several modes of heat transfer — radiation and convection from the outer surface, evaporation from both the surface and inner parts of the body and respiration involving both sensible and latent heat transfer. To maintain thermal equilibrium, the amount of heat produced or absorbed must equal the heat dissipated. The perception of thermal comfort is based on a range of variables: dry bulb temeprature; moisture content; air movement; surface temperatures; diect solar radiation.
2	Dry bulb air temperature	Dry bulb air temperature is the most commonly quoted factor in relation to thermal comfort. In a 'traditional" building, if the air temperature is within reasonable limits, it is likely that there is a reasonable degree of thermal comfort. This simple relationship between air temperature and comfort is less reliable in lighter weight modern buildings.
3	Moisture content	Humans will experience discomfort if the moisture content of the air in the room is either too dry, causing drying of the respiratory tract and eyes or too moist so that the body is unable to lose heat through evaporation (sweating) from the skin.
4	Air movement	The movement of air across the surface of the body affects the convective heat transfer from both the bare and clothed parts; over the exposed skin surfaces the flow of air is a factor in determining the transmission rate of moisture from the surface. If the combined effect of temperature and movement is too great then too much heat is removed and a subjective feeling of chill or draught results. Conversely, a high air temperature with little air movement will produce a subjective sensation of warmth that, although acceptable locally near a heating unit, is not tolerable throughout the general area of a room.
5	Surface temperatures	Experiments with test subjects in rooms with different air and surface temperatures have shown that, for optimum thermal comfort occupants prefer that the perceived surface temperatures (the mean radiant temperature) should be close to the air temperature. In real buildings, the inside surface temperatures can vary widely between surfaces. The human body is directionally sensitive to the radiation pattern — it cannot average multiple adverse effects to reach an acceptable condition therefore an imbalance can be conceived as uncomfortable.
6	Direct solar radiation -	If the occupants find themselves in the direct path of solar radiation transmitted through a glazed area, they may experience serious thermal discomfort. This will occur no matter how adequately the environmental systems are designed to cope with the solar and other loads.

7	Operative Temperatures	The CIBSE standard adopted in the UK for the assessment of comfort in an internal space is known as operative temperature (formerly known as dry resultant temperature); Toperative = (0.5xTair) + (0.5x Tradiant). This is in effect a simple average and so an increasing air temperature requires a corresponding reduction in radiant temperature if comfort is to be maintained. This can be achieved through reduced areas of glass, external shading, exposed concrete soffits and radiant cooling systems.
8	Sensible heat	When an object is heated, its temperature arises as heat is added. The increase in heat is called sendible heat. Similarly, when heat is removed from an object and its temperature falls, the heat removed is also called sensible heat. Heat that causes a change in temperature in an object is called sensible heat.
9	Latent heat	All pure substances in nature are able to change their state. Solids can become liquids and liquids can become gases but changes such as these require the addition of removal of heat. The heat that causes these changes is called lattent heat.
10	Summer By-pass	In summer months heat recovery is not desirable and therefore the MVHR unit diverts the incoming fresh air form the heat exchanger so that no heat recovery takes place
11	Predicted Mean Vote (PMV)	Predicted Mean Vote (PMV) is an example of a thermal comfort performance indicator. The Predicted Mean Vote (PMV) refers to a thermal scale that runs from Cold (-3) to Hot (+3), originally developed by Fanger and later adopted as an ISO standard.

Appendix 2 CIBSE TM52 Criteria

The CIBSE Overheating Task Force has decided that a new approach to the definition of overheating is necessary, particularly for buildings without mechanical cooling.

The following criteria, taken together, provide a robust yet balanced assessment of the risk of overheating of buildings in the UK and Europe. A room or building that fails any two of the three criteria is classed as overheating.

1. The first criterion sets a limit for the number of hours that the operative temperature can exceed the threshold comfort temperature (upper limit of the range of comfort temperature) by 1 K or more during the occupied hours of a typical non-heating season (1 May to 30 September).

2. The second criterion deals with the severity of overheating within any one day, which can be used as important as its frequency, the level of which is a function of both temperature rise and its duration. This criterion sets a daily limit for acceptability.

3. The third criterion sets an absolute maximum daily temperature for a room, beyond which the level of overheating is unacceptable.

CIBSE recommends that new buildings, major refurbishments and adaptation strategies should conform to Category II in BS EN 15251 (BSI, 2007) (for category definition see Table 2), which sets a maximum acceptable temperature of 3 °C above the comfort temperature for buildings in free-running mode.

Table 2 Suggested applicability of the categories and their associated acceptable temperature range for free-running buildings and of PMV for mechanically ventilated buildings (from BSI, 2007). The CIBSE suggestion is that designers should aim to remain within the Category II limits.

Category	Explanation	Suggested acceptable range (K)	Suggested acceptable limits PMV
I	High level of expectation only used for spaces occupied by very sensitive and fragile persons	± 2	± 0.2
II	Normal expectation (for new buildings and renovations)	± 3	± 0.5
III	A moderate expectation (used for existing buildings)	± 4	± 0.7
IV	Values outside the criteria for the above categories (only acceptable for a limited periods)	>4	> 0.7

For such buildings the maximum acceptable temperature (Tmax) can be calculated from the running mean of the outdoor temperature (Trm) (see Box 2) using the formula:

$$T_{max} = 0.33\ T_{rm} + 21.8$$

where Tmax is the maximum acceptable temperature (°C).

It should be noted that for buildings that have a higher level of expectation in respect to, say, spaces that are occupied by very sensitive and fragile persons, you may wish to agree with the client the more demanding standard suggested for Category I. This sets the maximum acceptable temperature (Tmax) at 1 K less than the above recommendation.

The criteria are all defined in terms of ΔT the difference between the actual operative temperature in the room at any time (Top) and Tmax the limiting maximum acceptable temperature. ΔT is calculated as:

$$\Delta T = Top - Tmax$$

ΔT is rounded to the nearest whole degree (i.e. for ΔT between 0.5 and 1.5 the value used is 1 K; for 1.5 to 2.5 the value used is 2 K, and so on).

(a) Criterion 1: Hours of exceedance (He)

The number of hours (He) during which ΔT is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3 per cent of occupied hours.

If data are not available for the whole period (or if occupancy is only for a part of the period) then 3 per cent of available hours should be used.

(b) Criterion 2: Daily weighted exceedance (W_e)

To allow for the severity of overheating the weighted exceedence (We) shall be less than or equal to 6 in any one day where:

$$W_e = (\Sigma h_e) \times WF$$

$$= (h_{e0} \times 0) + (h_{e1} \times 1) + (h_{e2} \times 2) + (h_{e3} \times 3)$$

where the weighting factor WF = 0 if ΔT ≤ 0, otherwise WF = ΔT, and h_{ey} is the time (h) when WF = y.

Thus suppose we have a room where the temperature is simulated or monitored at half-hourly intervals over 8 occupied hours, so we have 16 readings, ten of them where ΔT is zero or negative (WF = 0), three readings where ΔT = 1 (WF = 1), two where ΔT = 2 (WF = 2) and one where ΔT = 3 (WF = 3) then:

$$W_e = ½ [(10 \times 0) + (3 \times 1) + (2 \times 2) + (1 \times 3)]$$

= 5 (i.e. the criterion is fulfilled)

(c) Criterion 3: Upper limit temperature (Tupp)

To set an absolute maximum value for the indoor operative temperature the value of ΔT shall not exceed 4 K.

Appendix 3 CIBSE GUIDE A (2006) Environmental Design-Overheating criteria

The Chartered Institute of Building Service Engineers in CIBSE Guide A (2006) sets out methodologies for analysing overheating in buildings and numerical guidelines and benchmarks for suggested maximum acceptable internal dry bulb temperatures in dwellings.

According to CIBSE Guide A - benchmarks for summer temperatures for dwellings, the annual number of hours of internal temperatures greater than 26ºC in bedrooms and 28ºC in living areas should not be greater than 1% of the total annual occupied hours. Please refer to the table below:

Building Type	Room type	Benchmark Summer Peak Temperature C°	Overheating Criterion
Dwellings	Bedrooms	26°C	Maximum 1% annual occupied hours over operative temperature of 26 °C
	Living areas	28°C	Maximum 1% annual occupied hours over operative temperature of 28 °C
Non Residential	Example: Offices, schools	28°C	Maximum 1% annual occupied hours over operative temperature of 28 °C

Appendix 4 Detailed simulation results

Current weather data (2005):Base case

Current DSY (2005)_Base case	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0.4	6	2	-
PL265_GF_Living	0.3	5	1	-
PL265_1stFL_BedAx2	0.4	8	2	2
PL265_1stFL_BedBx2	0.3	7	2	2
PL265_1stFL_BedCx1	0.3	7	2	2
Plot 281				
PL281_GF_Kitchen	0.4	7	2	2
PL281_GF_Living	0.1	2	1	-
PL281_1stFL_BedAx2	0.6	12	3	2
PL281_1stFL_BedBx2	0.3	6	2	-
PL281_1stFL_BedCx2	3.5	29	4	1 & 2
Plot 288				
PL288_GF_Kitchen	0.4	5	2	-
PL288_GF_Living/Dining	0.3	5	1	-
PL288_1stFL_BedAx2	0.3	5	1	-
PL288_1stFL_BedBx2	0.3	6	2	-
PL288_1stFL_BedCx1	0.2	4	1	-

Current weather data (2005):Blinds

Current DSY (2005)_Blinds	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0.3	4	1	-
PL265_GF_Living	0.1	2	1	-
PL265_1stFL_BedAx2	0.3	2	1	-
PL265_1stFL_BedBx2	0.2	2	1	-
PL265_1stFL_BedCx1	0.1	2	1	-
Plot 281				
PL281_GF_Kitchen	0.4	8	2	2
PL281_GF_Living	0.1	2	1	-
PL281_1stFL_BedAx2	0.8	17	2	2
PL281_1stFL_BedBx2	0.4	11	2	2
PL281_1stFL_BedCx2	3.6	34	5	1 & 2 & 3
Plot 288				
PL288_GF_Kitchen	0.3	3	1	-
PL288_GF_Living/Dining	0	1	1	-
PL288_1stFL_BedAx2	0	1	1	-
PL288_1stFL_BedBx2	0.1	4	1	-
PL288_1stFL_BedCx1	0	1	1	-

Current weather data (2005): Night-time cooling

CURRENT DSY (2005)_NC	Criteria 1 (%Hrs Top-Tmax>=1 K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0.3	3	1	-
PL265_GF_Living	0.2	3	1	-
PL265_1stFL_BedAx2	0.1	4	1	-
PL265_1stFL_BedBx2	0.1	3	1	-
PL265_1stFL_BedCx1	0.1	2	1	-
Plot 281				
PL281_GF_Kitchen	0.3	3	1	-
PL281_GF_Living	0.2	3	1	-
PL281_1stFL_BedAx2	0.8	15	3	2
PL281_1stFL_BedBx2	0.3	9	2	2
PL281_1stFL_BedCx2	5.2	35	5	1 & 2 & 3
Plot 288				
PL288_GF_Kitchen	0.4	5	2	-
PL288_GF_Living/Dining	0.3	5	1	-
PL288_1stFL_BedAx2	0.2	4	1	-
PL288_1stFL_BedBx2	0.3	5	1	-
PL288_1stFL_BedCx1	0.2	4	1	-

Current weather data (2005): Blinds along with night-time cooling

CURRENT DSY (2005) BL&NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0.3	3	1	-
PL265_GF_Living	0.2	3	1	-
PL265_1stFL_BedAx2	0	0	0	-
PL265_1stFL_BedBx2	0	0	0	-
PL265_1stFL_BedCx1	0	0	0	-
Plot 281				
PL281_GF_Kitchen	0.3	4	1	-
PL281_GF_Living	0	1	1	-
PL281_1stFL_BedAx2	0.4	9	2	2
PL281_1stFL_BedBx2	0.1	4	1	-
PL281_1stFL_BedCx2	2.7	26	4	2
Plot 288				
PL288_GF_Kitchen	0.3	3	1	-
PL288_GF_Living/Dining	0	1	1	-
PL288_1stFL_BedAx2	0	1	1	-
PL288_1stFL_BedBx2	0.1	4	1	-
PL288_1stFL_BedCx1	0	1	1	-

Future weather data (2030): Base case

Future climatic data (2030)_Base case	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0.4	5	1	-
PL265_GF_Living	0.2	4	2	-
PL265_1stFL_BedAx2	0.4	9	2	-
PL265_1stFL_BedBx2	0.3	5	1	-
PL265_1stFL_BedCx1	0.1	2	1	-
Plot 281				
PL281_GF_Kitchen	0	0	0	0
PL281_GF_Living	0	0	0	0
PL281_1stFL_BedAx2	2.7	16	3	2
PL281_1stFL_BedBx2	1.9	13	2	2
PL281_1stFL_BedCx2	9	41	6	1&2&3
Plot 288				
PL288_GF_Kitchen	0.6	4	2	-
PL288_GF_Living/Dining	0.1	2	1	-
PL288_1stFL_BedAx2	0.1	1	1	-
PL288_1stFL_BedBx2	0.2	2	1	-
PL288_1stFL_BedCx1	0	2	1	-

Future weather data (2030): Blinds

Future climatic data (2030)_Blinds	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0.1	1	1	-
PL265_GF_Living	0	0	0	-
PL265_1stFL_BedAx2	0.1	2	1	-
PL265_1stFL_BedBx2	0	1	1	-
PL265_1stFL_BedCx1	0	0	0	-
Plot 281				
PL281_GF_Kitchen	0.5	3	1	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	1.8	11	2	2
PL281_1stFL_BedBx2	0.8	7	2	2
PL281_1stFL_BedCx2	5.7	27	4	1 & 2
Plot 288				
PL288_GF_Kitchen	0.3	1	1	-
PL288_GF_Living/Dining	0	0	0	-
PL288_1stFL_BedAx2	0	0	0	-
PL288_1stFL_BedBx2	1	5	1	-
PL288_1stFL_BedCx1	1	2	1	-

Future weather data (2030): Night-time cooling

Future climatic data (2030)_NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0	0	0	-
PL265_GF_Living	0	1	1	-
PL265_1stFL_BedAx2	0	1	1	-
PL265_1stFL_BedBx2	0	0	0	-
PL265_1stFL_BedCx1	0	0	0	-
Plot 281				
PL281_GF_Kitchen	0.4	3	1	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	1.5	9	2	2
PL281_1stFL_BedBx2	0.4	5	1	-
PL281_1stFL_BedCx2	7	33	5	1&2&3
Plot 288				
PL288_GF_Kitchen	0.5	3	2	-
PL288_GF_Living/Dining	0.1	2	1	-
PL288_1stFL_BedAx2	0.1	1	1	-
PL288_1stFL_BedBx2	0.1	2	1	-
PL288_1stFL_BedCx1	0	1	1	-

Future weather data (2030): Blinds along with night-time cooling

Future climatic data (2030)_BL&NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	0	0	0	-
PL265_GF_Living	0	0	0	-
PL265_1stFL_BedAx2	0	0	0	-
PL265_1stFL_BedBx2	0	0	0	-
PL265_1stFL_BedCx1	0	0	0	-
Plot 281				
PL281_GF_Kitchen	0	1	1	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	0.8	5	2	-
PL281_1stFL_BedBx2	0	1	1	-
PL281_1stFL_BedCx2	4.2	22	4	1 & 2
Plot 288				
PL288_Kitchen	0.3	1	1	-
PL288_Living/Dining	0	0	0	-
PL288_BedAx2	0	0	0	-
PL288_BedBx2	0	0	0	-
PL288_BedCx1	0	0	0	-

Future weather data (2050): Base case

Future climatic data (2050)_Base case	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	3	16	3	2
PL265_GF_Living	1.9	15	3	2
PL265_1stFL_BedAx2	2.3	11	2	2
PL265_1stFL_BedBx2	2.7	10	2	2
PL265_1stFL_BedCx1	1.6	8	2	2
Plot 281				
PL281_GF_Kitchen	2.6	14	3	2
PL281_GF_Living	4.5	18	3	1 & 2
PL281_1stFL_BedAx2	6.6	26	4	1 & 2
PL281_1stFL_BedBx2	5.4	22	3	1 & 2
PL281_1stFL_BedCx2	11.6	51	6	1&2&3
Plot 288				
PL288_GF_Kitchen	1.4	12	2	2
PL288_GF_Living/Dining	3.1	14	3	1 & 2
PL288_1stFL_BedAx2	1.8	13	2	2
PL288_1stFL_BedBx2	2	13	2	2
PL288_1stFL_BedCx1	1.4	12	2	2

Future weather data (2050): Blinds

Future climatic data (2050)_Blinds	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	2.3	12	3	2
PL265_GF_Living	1.1	11	2	2
PL265_1stFL_BedAx2	1.1	9	2	2
PL265_1stFL_BedBx2	1.8	7	2	2
PL265_1stFL_BedCx1	0.5	5	1	-
Plot 281				
PL281_GF_Kitchen	3.1	16	3	1 & 2
PL281_GF_Living	1.5	11	2	2
PL281_1stFL_BedAx2	4.6	20	4	1 & 2
PL281_1stFL_BedBx2	3.3	13	3	1 & 2
PL281_1stFL_BedCx2	9	37	5	1 & 2 & 3
Plot 288				
PL288_Kitchen	2.3	11	3	2
PL288_Living/Dining	0.4	6	1	-
PL288_BedAx2	0.9	5	1	-
PL288_BedBx2	0.8	8	2	2
PL288_BedCx1	0.5	6	1	-

Future weather data (2050): Night-time cooling

Future climatic data (2050)_NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	2	14	3	2
PL265_GF_Living	1.3	12	2	2
PL265_1stFL_BedAx2	0.5	4	1	-
PL265_1stFL_BedBx2	0.5	4	1	-
PL265_1stFL_BedCx1	0.2	4	1	-
Plot 281				
PL281_GF_Kitchen	2.6	16	3	2
PL281_GF_Living	1.5	11	2	2
PL281_1stFL_BedAx2	3.1	16	3	1 & 2
PL281_1stFL_BedBx2	1.7	11	2	2
PL281_1stFL_BedCx2	9.4	39	5	1 & 2 & 3
Plot 288				
PL288_Kitchen	3.1	14	3	1 & 2
PL288_Living/Dining	1.1	11	2	2
PL288_BedAx2	1.5	12	2	2
PL288_BedBx2	1.9	13	2	2
PL288_BedCx1	1.3	11	2	2

Future weather data (2050): Blinds along with night-time cooling

Future climatic data (2050)_BL&NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Plot 265				
PL265_GF_Kitchen	1.5	10	3	2
PL265_GF_Living	0.5	9	2	2
PL265_1stFL_BedAx2	0.1	3	1	-
PL265_1stFL_BedBx2	0.1	2	1	-
PL265_1stFL_BedCx1	0	1	1	-
Plot 281				
PL281_GF_Kitchen	1.9	12	3	2
PL281_GF_Living	0.8	8	2	2
PL281_1stFL_BedAx2	1.8	11	3	2
PL281_1stFL_BedBx2	0.9	7	2	2
PL281_1stFL_BedCx2	6.5	27	4	1 & 2
Plot 288				
PL288_Kitchen	2.3	11	3	2
PL288_Living/Dining	0.4	6	1	-
PL288_BedAx2	0.9	5	1	-
PL288_BedBx2	0.8	8	2	2
PL288_BedCx1	0.5	6	1	-

Current weather data (2005)_Plot 281 iterations: Base case

PL281-Currrent climatic data (2005)_Base case	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0.8	12	2	2
PL281_GF_Living	0.4	6	2	-
PL281_1stFL_BedAx2	1.5	21	4	2
PL281_1stFL_BedBx2	1	16	3	2
PL281_1stFL_BedCx2	4.7	37	5	1&2&3
Overhang				
#PL281_GF_Kitchen	0.8	12	2	2
#PL281_GF_Living	0.4	6	2	-
#PL281_1stFL_BedAx2	1.5	22	4	2
#PL281_1stFL_BedBx2	1	18	3	2
#PL281_1stFL_BedCx2	5.3	37	5	1&2&3

Current weather data (2005)_Plot 281 iterations: Blinds

PL281-Currrent climatic data (2005)_Blinds	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0.4	8	2	2
PL281_GF_Living	0.1	2	1	-
PL281_1stFL_BedAx2	1	16	3	2
PL281_1stFL_BedBx2	0.5	10	2	2
PL281_1stFL_BedCx2	2.3	29	4	2
Overhang				
#PL281_GF_Kitchen	0.4	8	2	2
#PL281_GF_Living	0.1	2	1	-
#PL281_1stFL_BedAx2	1	17	3	2
#PL281_1stFL_BedBx2	0.5	10	2	2
#PL281_1stFL_BedCx2	2.8	29	4	2

Current weather data (2005)_Plot 281 iterations: Night-time cooling

PL281-Currrent climatic data (2005)_NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0.4	7	2	2
PL281_GF_Living	0.1	2	1	-
PL281_1stFL_BedAx2	0.6	12	3	2
PL281_1stFL_BedBx2	0.3	6	2	-
PL281_1stFL_BedCx2	3.5	29	4	1 & 2
Overhang				
#PL281_GF_Kitchen	0.4	7	2	2
#PL281_GF_Living	0.1	2	1	-
#PL281_1stFL_BedAx2	0.7	12	3	2
#PL281_1stFL_BedBx2	0.3	8	2	2
#PL281_1stFL_BedCx2	4.2	29	4	1 & 2

Current weather data (2005)_Plot 281iterations: Blinds with night-time cooling

PL281-Currrent climatic data (2005)_BL&NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0.2	3	1	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	0.3	9	2	2
PL281_1stFL_BedBx2	0.1	3	1	-
PL281_1stFL_BedCx2	1.5	17	3	2
Overhang				
#PL281_GF_Kitchen	0.2	3	1	-
#PL281_GF_Living	0	0	0	-
#PL281_1stFL_BedAx2	0.3	9	2	2
#PL281_1stFL_BedBx2	0.1	4	1	-
#PL281_1stFL_BedCx2	1.8	21	3	2

Future weather data (2030)_Plot 281 iterations: Base case

PL281-Future climatic data (2030)_Base case	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0.7	4	2	-
PL281_GF_Living	0.2	2	1	-
PL281_1stFL_BedAx2	2.4	14	3	2
PL281_1stFL_BedBx2	1.7	11	2	2
PL281_1stFL_BedCx2	6.9	34	5	1&2&3
Overhang				
#PL281_GF_Kitchen	0.7	4	2	-
#PL281_GF_Living	0.2	2	1	-
#PL281_1stFL_BedAx2	2.6	15	3	2
#PL281_1stFL_BedBx2	1.8	12	2	2
#PL281_1stFL_BedCx2	7.8	38	6	1&2&3

Future weather data (2030)_Plot 281 iterations: Blinds

PL281-Future climatic data (2030)_Blinds	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0.4	3	1	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	1.5	11	2	2
PL281_1stFL_BedBx2	0.6	6	1	-
PL281_1stFL_BedCx2	4.1	21	3	1 & 2
Overhang				
#PL281_GF_Kitchen	0.4	3	1	-
#PL281_GF_Living	0	0	0	-
#PL281_1stFL_BedAx2	1.7	11	2	2
#PL281_1stFL_BedBx2	0.7	6	1	-
#PL281_1stFL_BedCx2	4.5	26	4	1 & 2

Future weather data (2030)_Plot 281 iterations: Night-time cooling

PL281-Future climatic data (2030)_NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0.4	3	1	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	1.1	8	2	2
PL281_1stFL_BedBx2	0.2	4	1	-
PL281_1stFL_BedCx2	4.8	25	4	1 & 2
Overhang				
#PL281_GF_Kitchen	0.4	3	1	-
#PL281_GF_Living	0	0	0	-
#PL281_1stFL_BedAx2	1.3	8	2	2
#PL281_1stFL_BedBx2	0.3	5	1	-
#PL281_1stFL_BedCx2	5.8	31	5	1&2&3

Future weather data (2030)_Plot 281 iterations: Blinds with night-time cooling

PL281-Future climatic data (2030)_BL&NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	0	0	0	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	0.4	4	1	-
PL281_1stFL_BedBx2	0	0	0	-
PL281_1stFL_BedCx2	2.3	17	3	2
Overhang				
PL281_GF_Kitchen	0	0	0	-
PL281_GF_Living	0	0	0	-
PL281_1stFL_BedAx2	0.5	5	2	-
PL281_1stFL_BedBx2	0	0	0	-
PL281_1stFL_BedCx2	2	19	3	2

Future weather data (2050)_Plot 281 iterations: Base case

PL281-Future climatic data (2050)_Base case	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	4.4	18	3	1 & 2
PL281_GF_Living	2.6	14	3	2
PL281_1stFL_BedAx2	6.5	31	4	1 & 2
PL281_1stFL_BedBx2	5.2	23	3	1 & 2
PL281_1stFL_BedCx2	10	43	5	1&2&3
Overhang				
#PL281_GF_Kitchen	4.5	18	3	1 & 2
#PL281_GF_Living	2.6	13	3	2
#PL281_1stFL_BedAx2	6.8	33	4	1 & 2
#PL281_1stFL_BedBx2	5.3	23	3	1 & 2
#PL281_1stFL_BedCx2	10.6	45	6	1&2&3

Future weather data (2050)_Plot 281 iterations: Blinds

PL281-Future climatic data (2050)_Blinds	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	3	16	3	2
PL281_GF_Living	1.5	11	2	2
PL281_1stFL_BedAx2	4.4	20	3	1 & 2
PL281_1stFL_BedBx2	3.2	14	2	1 & 2
PL281_1stFL_BedCx2	7.3	33	4	1 & 2
Overhang				
#PL281_GF_Kitchen	3.1	16	3	1 & 2
#PL281_GF_Living	1.5	11	2	2
#PL281_1stFL_BedAx2	4.7	21	4	1 & 2
#PL281_1stFL_BedBx2	3.5	15	3	1 & 2
#PL281_1stFL_BedCx2	8	35	5	1&2&3

Future weather data (2050)_Plot 281 iterations: Night-time cooling

PL281-Future climatic data (2050)_NC	Criteria 1 (%Hrs Top-Tmax>=1K)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Spandrel panel				
PL281_GF_Kitchen	2.4	16	3	2
PL281_GF_Living	1.5	11	2	2
PL281_1stFL_BedAx2	2.5	16	3	2
PL281_1stFL_BedBx2	1.4	10	2	2
PL281_1stFL_BedCx2	6.9	32	4	1 & 2
Overhang				
#PL281_GF_Kitchen	2.6	16	3	2
#PL281_GF_Living	1.5	11	2	2
#PL281_1stFL_BedAx2	2.6	15	3	2
#PL281_1stFL_BedBx2	1.5	11	2	2
#PL281_1stFL_BedCx2	7.7	33	4	1 & 2