PRP

Bicester Ecotown Phases 3 and 4, Oxfordshire

Overheating Analysis and Climate Change Mitigation

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Author	Carolina Caneva
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1 INTRODUCTION

1.1 The Development Consultancy at PRP has been commissioned by Crest Nicholson to carry out an overheating and climate change mitigation analysis on selected worst case houses within Phases 3 and 4 of Bicester Ecotown, Oxfordshire development.

1.2 One of the key aims of this study is to investigate the impact of climate change on these specific houses in Bicester and examine any potential risk of summer overheating that these buildings on Phases 3 and 4 may suffer from today and in the future as per Planning Policy Statement for Eco-towns (PPS1). It is therefore a primary scope of this report to assess summer overheating risks for the current weather scenario and two more future weather projections (2030 and 2050), according to the requirements of Planning Condition 10:

> *10. Prior to commencement of residential development in each phase a study, by a suitably qualified person, shall be submitted to and approved in writing by the local planning authority, demonstrating that the design of the dwellings within that phase is such that overheating will not occur and that heat island effects have been minimised. The development shall thereafter be carried out in accordance with the agreed details*
>
> *Reason: To address the impacts of climate change in accordance with Planning Policy Statement 1: Eco Towns*

1.3 The analysis was undertaken using the parameters and guidelines by CIBSE TM52:2013 'The limits of thermal comfort: avoiding overheating in European buildings', which replaces the guidelines defined under CIBSE Guide A 'Environmental Design'. TM52 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).

1.4 The following three different types dwellings (out of the main 7 types), deemed to be representative of worst case scenarios within the analysed houses, were modelled to assess their overheating risk. In addition, this assessment aims to identify how the changes proposed in the design affect the internal temperatures up to the year of 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.

- **Private House 120** - 3 bedrooms (3B5P)
- **Private House 49 -** 5 bedrooms (5B9P)
- **Private House 227**- 5 bedrooms (5B10P)

1.5 The location, layout and design are illustrated in Figures 1 to 7, in section 3.

1.6 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 presented as part of this report (section 3). These should be read carefully to gain an understanding of the parameters of the modelling. The following options have been tested for each unit using a number of assumptions:

- **Base case:** Section 3 below describes in detail the assumptions for the base case simulation.
- **Option 1:** Utilise night time cooling
- **Option 2:** Assign internal blinds to all of the windows
- **Option 3:** Combine blinds with night time cooling
- **Option 4:** Combine blinds, night time cooling and increase of ventilation

1.7 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 and actual occupancy situations.

2 CRITERIA

Methodology and Overheating Criteria

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

2.2 For this analysis, the methodology was based on the criteria set out by CIBSE TM52: 2013 'The limits of thermal comfort: avoiding overheating in European buildings', which is explained in more detailed in Appendix 2.The following guidelines define overheating in free-running buildings according to TM52:

- **Criteria 1:** Hours of Exceedance (He):

  The first criterion sets a limit for the frequency of overheating, by measuring the number of hours (He) that the operative temperature (Top) can exceed the threshold comfort temperature (Tmax) by 1ºK or more during the occupied hours of a typical non-heating season (1 May to 30 September); the exceedance shall not be more than **3% of occupied hours**.

- **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 hours** in 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 (difference between the actual operative temperature in the room at any time (Top) and Tmax the limiting maximum acceptable temperature) shall not exceed **4ºK**.

2.3 These criteria represent the applicable guidance from CIBSE to this project 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:

2.4 It has been assumed that the analysed dwellings fall under the Category II of CIBSE recommendations shown in Table 1 below:

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

3 ANALYSIS

Geometry, Location and Zone Layouts

3.1 The site is located on the edge of Bicester, Oxfordshire. Figure 1 below shows the location of Phases 3 & 4, within the development site. This image also shows the surrounding buildings to the modelled dwellings, as they were considered to be obstructions that shaded the selected units. Overall Phases 3 and 4 have 228 houses and main 7 dwellings types: 2B4P, 3B5P, 4B6P, 4B7P, 5B9P, 5B9P(V3), and 5B10P.

Methodology

3.2 The methodology used for this analysis followed an initial desktop assessment to determine the worst-case scenario units to be modelled, which are located in Phases 3 and 4of Bicester Ecotown development. The selection criteria were based on the following:

- Orientation: South and West facing dwellings will suffer from the high altitude 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 higher solar heat gains conducted through the building envelope into the dwelling
- Potential Heat loses.

3.3 All dwellings were considered and analysed as part of the desktop analysis. As a result of the desktop analysis the 3 worst performing (and modelled) units were identified and are the following:

- Unit 49 (13 units of this type)
- Unit 120 (83 units of this type)
- Unit 227 (4 units of this type)

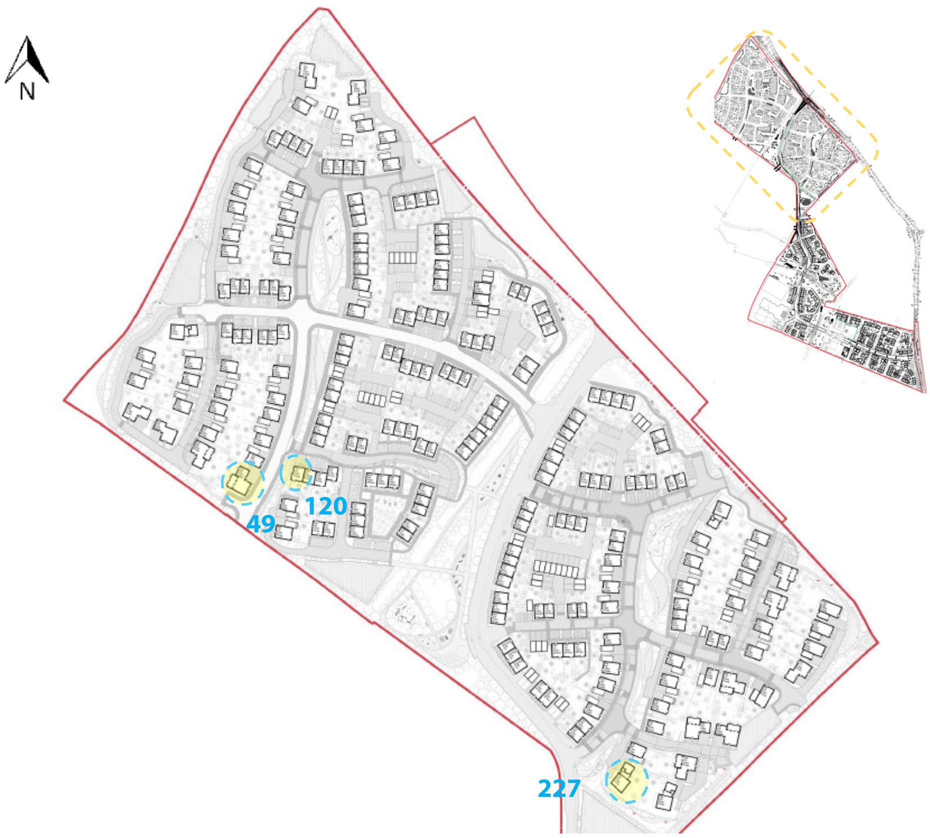


Figure 1 - Location of the units subject to design change assessed in Phases 3 and 4 of Bicester Ecotown

Dynamic Modelling

3.4 Dynamic thermal analysis has been performed only on the selected units 49, 120 and 227, which were considered the expected worst case scenarios, in order to assess the resulting conditions during the course of a design year. The analysis accounts for the characteristics of each habitable space, including the internal gains, building fabric details, building orientation and external weather conditions.

3.5 The thermal model of the proposed development was constructed using Integrated Environmental Solutions (IES-VE) version 2017.2.0.0, which complies with CIBSE Applications Guide AM11 'Building Energy and Environmental Modelling'

3.6 For the current weather year analysis, the Design Summer Years (DSY) and the projected weather year's data for 2030 and 2050, the weather data for the Bicester area has been used, which has been sourced from the Prometheus database.

3.7 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."

3.8 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.

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

UNIT 49 - 5 bed (9 people), Private House

3.10 Figure 3 below shows plans of the house type that corresponds to unit 49, which 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.

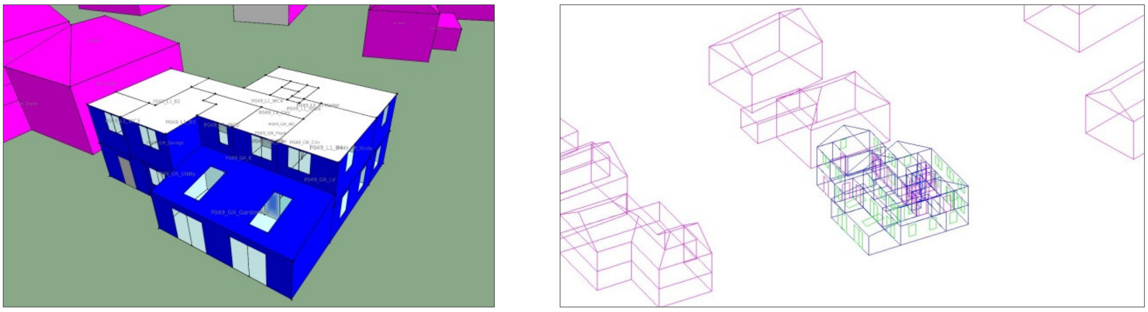


Figure 2 - Dwelling 49

Figure 3 - Dwelling 49 ground and first floor plans and analysed rooms highlighted.

UNIT 120 - 3 bed (5 people), Private House

3.11 Figure 5 below shows plans of the house type that corresponds to unit 120, which 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.

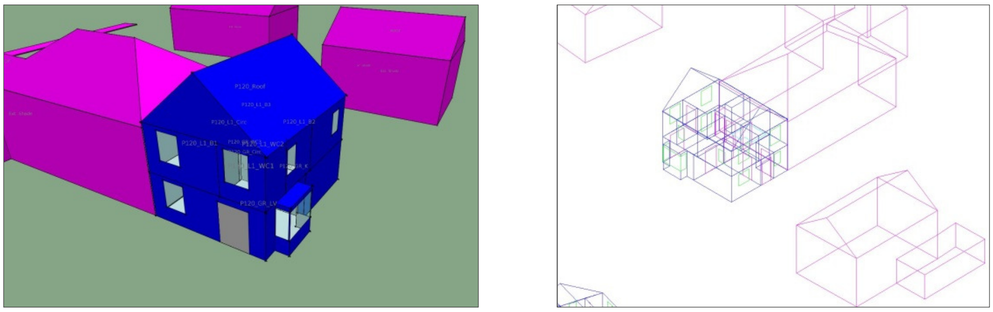


Figure 4 - Dwelling 120

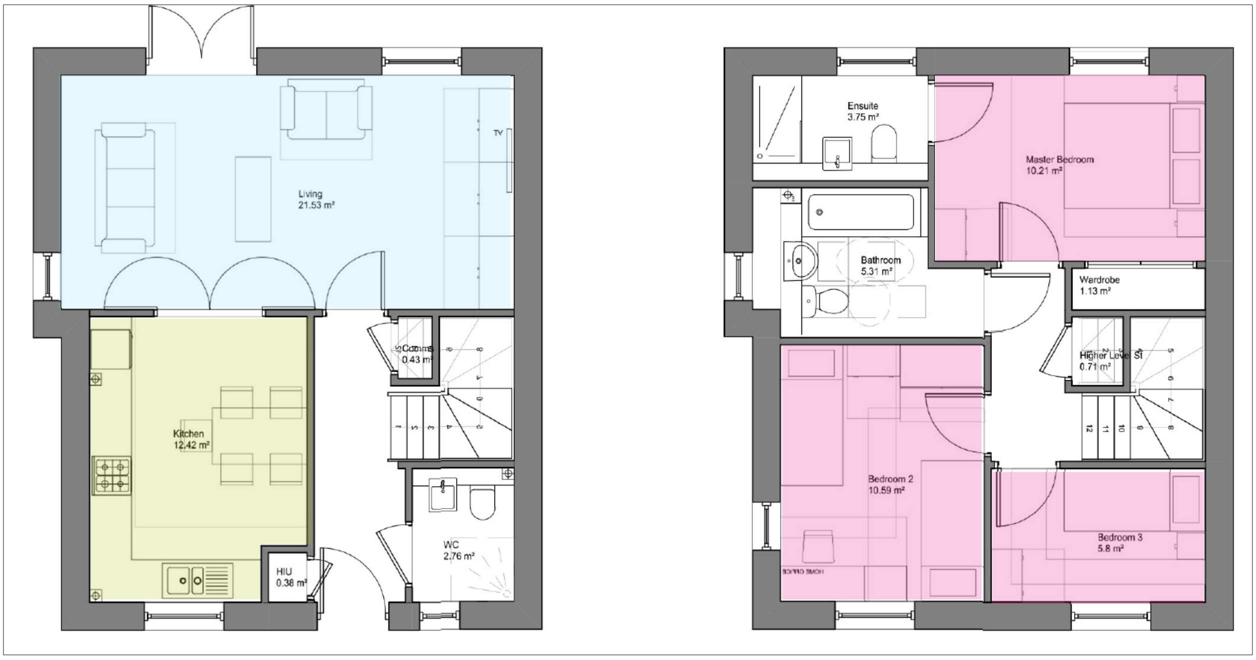


Figure 5 - Dwelling 120 ground and first floor plans and analysed rooms highlighted.

UNIT 227 - 5 bed (10 people), Private House

3.12 Figure 7 below shows plans of the house type that corresponds to unit 227, which 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.

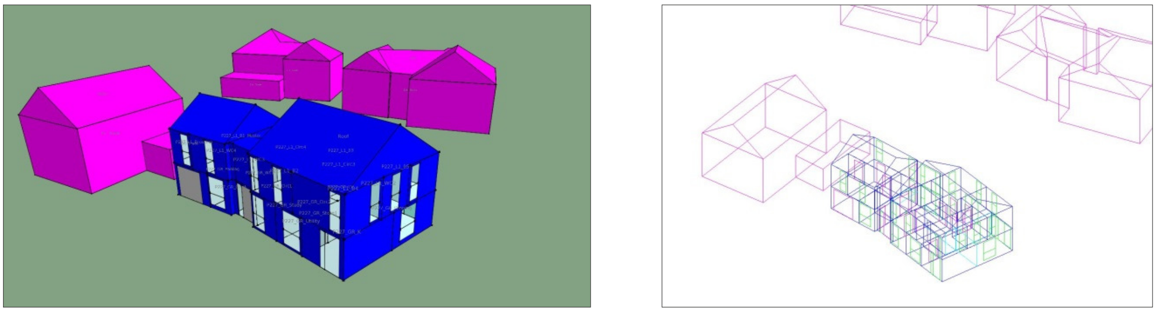


Figure 6 - Dwelling 227

Figure 7 - Dwelling 227 ground and first floor plans and analysed rooms highlighted.

Building Elements

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

Table 2 - Building elements

Building Elements		Construction / Materials	U-value W/m² °C
WALLS	External	Timber frame superstructure with 103mm facing brickwork to outer leaf	0.12 - 0.15
	Internal	• Plasterboard • Timber Studwork • Plasterboard	-
	Ground	• Vinyl finish • Insulation (50mm) • Flooring screed • EPS Insulated Block flooring system (90mm) • Brick slips	0.15 Semi-exposed 0.11
	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	0.10 - 0.13
OPENINGS	Windows	• Triple glazing (6mm) • 16mm Argon filled cavity	0.85 G-value= 0.53
	Main Door	• Softwood • Insulation • Plywood	1.10
	Internal doors	• Wood	2.20

Internal Gains

3.14 Occupancy, lighting and equipment gains were based on NCM (National Calculation Methodology) for domestic properties.

Table 3 - Internal gains

Space	Thermal Conditions	Lighting Gain (W/m²)	Occupancy gains (W/person)		Equipment gains (W/m²)	
			Sensible	Latent	Sensible	Latent
Dining	NCM_Dwell_DomDining_Wk1	7.8	67.1	42.9	3.0	0
Kitchen	NCM_Dwell_DomKitchen_Wk1	15.6	56.0	104.0	20.6	9.7
Living rooms	NCM_Dwell_DomLounge_Wk1	7.8	67.1	42.9	3.9	0
Bathroom	NCM_Dwell_DomBath_Wk1	7.8	60.0	60.0	1.7	0
Bedroom	NCM_Dwell_DomBed_Wk1	5.2	67.5	22.5	2.9	0.7
Study	NCM_Dwell_DomLounge_Wk1	7.8	67.1	42.9	3.9	0
	SCHEDULE USED	Lighting **5-9am & 6.30-10.30pm** (varies for different rooms)	Profile Selected is **MEDIUM HIGH (0-9am & 4.30-0pm)**		Equipment: **5-9am & 6.30-10.30pm** (varies for different rooms)	

Ventilation

3.15 Natural ventilation is possible via openable windows and doors.

Table 4 - Aperture schedule and profile

APERTURES	Room	Profile: Starts opening when adjacent zone at:	Profile: Fully opened adjacent zone at:
Windows	First Floor (75% openable)	20ºC	23ºC
	Ground Floor (75% openable)	20ºC	23ºC
	Night Cooling (when Applicable)	Windows open all the time, except when house not occupied during the daytime period	
No restrictors have been assumed for the windows. All the windows will be closed if external temperature is higher than internal temperature.			
Doors	External	Opened 20min of occupied hours, equivalent to 2%	
	Internal	100% opened whole day time and 10% during the night	

3.16 It has been assumed that the occupants will open their windows when the internal temperatures exceed 20ºC to 23°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.

3.17 In order to maximise natural ventilation within the dwelling extract ventilation will be installed within the kitchen and bathroom areas.

Infiltration

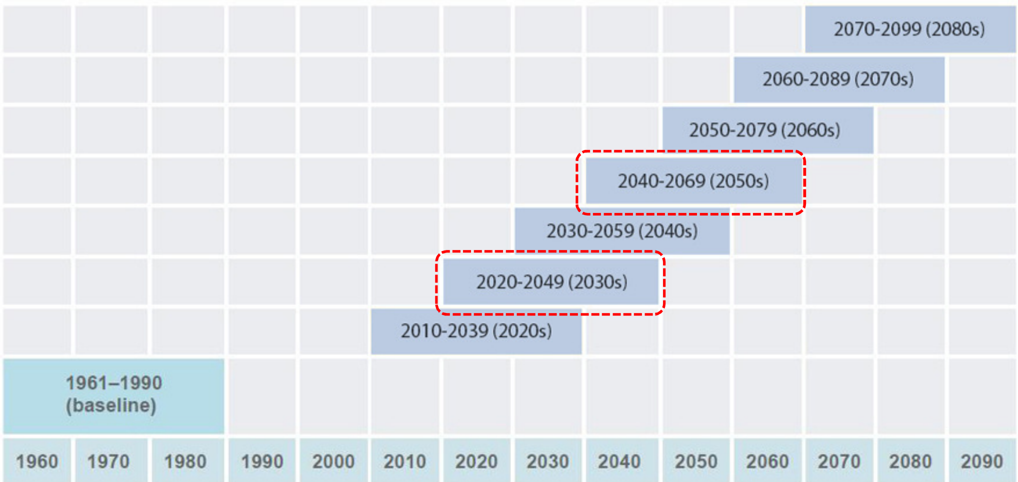
3.18 An air infiltration rate of 0.155ACH, which is equivalent to air tightness of 3.0m^3/hr/m^2@50Pa, has been assumed in this analysis.

Weather data

3.19 The weather data used for this study is detailed as follows:

- **Current weather year file:** *DSY* (Design Summer Year) weather data, under the Prometheus programme;
- **Projected weather files.** MEDIUM Emissions Scenario; these files were provided by University of Exeter, under the Prometheus programme.
    - *UK _Bicester_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 _Bicester_2050_a1b_90Percentil*

3.20 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.



Occupancy Profiles

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

- **Weekdays:** Working Hours (4pm to 10am)
- **Weekends:** 24 hours

4 ITERATIONS

4.1 A number of iterations have been tested for each of the climatic data, first being a purge mechanism through (night time) ventilation and the second being a solar shading device (internal blinds). Both measures have been tested in combination, in order to evaluate the optimum mitigation scenario for all of the houses. Units 270 and 272 have been tested further with different design alterations for each of the climatic data due to higher risks identified.

Single

- **Night Cooling (NC)**

4.2 The model was re-run with windows opened during night time (7pm to 9am). These allow the building fabric to cool as external temperatures drop allowing heat gains absorbed during the day to be naturally removed from the internal spaces. The night time cooling measure does not require any additional cost or material production, while at the same time is bringing a significant reduction in overheating hours.

4.3 According to the simulation results 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.

- **Solar Shading (Blinds)**

4.4 Solar shading, in the form of internal temporary blinds, has been incorporated into all of the windows in each unit. The window blinds are assumed to be closed from 9am to 8pm to protect the internal spaces from solar gains.

Combined

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

4.5 This iteration combines night time cooling 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.

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

4.6 This iteration combines the previous two iterations and also the natural ventilation is increased opening the windows to its maximum opening and allowing other panes of the windows to be openable. This combination allows the heat to be released at night, similar to the previous combination.

6 RESULTS AND DISCUSSIONS

6.1 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 two of the three criteria (thus overheating, according to the CIBSE TM52)
- High Risk, for rooms failing the three criteria

6.2 A summary of the results showing the percentage of rooms passing the overheating criteria.

Plot No.	Scenario	CURRENT					2030					2050				
	Iteration	BaseCase	Night Cooling	Blinds	Blinds + NC	Blinds+NC+ Ventilation	BaseCase	Night Cooling	Blinds	Blinds + NC	Blinds+NC+ Ventilation	BaseCase	Night Cooling	Blinds	Blinds + NC	Blinds+NC+ Ventilation
Plot 049	No. Rooms Passing	5	8	8	8	8	0	0	8	8	8	0	0	3	7	8
(8 Rooms)	% of Passing	63%	100%	100%	100%	100%	0%	0%	100%	100%	100%	0%	0%	38%	88%	100%
Plot 120	No. Rooms Passing	5	5	5	5	5	3	4	5	5	5	0	0	5	5	5
(5 Rooms)	% of Passing	100%	100%	100%	100%	100%	60%	80%	100%	100%	100%	0%	0%	100%	100%	100%
Plot 227	No. Rooms Passing	3	4	9	9	9	0	0	5	9	9	0	0	0	2	9
(9 Rooms)	% of Passing	33%	44%	100%	100%	100%	0%	0%	56%	100%	100%	0%	0%	0%	22%	100%

6.3 The results are presented in more detail in the table overleaf, which compiles the year tested and the mitigation measures applied to reduce the overheating risk. Overall, according to the results the main risk of overheating is primarily identified within the bedrooms of Plot 227 for the current weather scenario (where the bedrooms fail either two or three of the CIBSE TM2 criteria). When the model analyses the risk in the year 2030 scenario, then in addition to Plot 227, the majority of the bedrooms located in Plot 049 also are at high risk of overheating. For the year 2050 all rooms in all plots are at high risk of overheating (failing all 3 CIBSE TM52 criteria), with the exception of bedroom 1 in Plot 120 (minor risk).

6.4 The first mitigation measure tested was the introduction of night time cooling. This measure alone has proven effective in reducing the risk of overheating on the current weather scenario with only 3 bedrooms, in Plot 227 at high risk. In the 2030 weather scenario night time cooling completely eliminated the high risk of overheating in Plot 120, restricted the high risk to only three bedrooms in Plot 049 and hasn't proven enough to reduce or eliminate the occurrence of high risk in Plot 227. For the year 2050 all rooms in Plot 227, 120 and 049 are indicating a high risk of overheating (failing all 3 CIBSE TM52 criteria). The only exception is again (as in the current weather scenario) is bedroom 1 in Plot 120, which seems to be at minor risk of overheating (fails 2 of the 3 CIBSE TM52 criteria).

6.5 Given the results achieved with the introduction of night time cooling, a second mitigation measure was tested: introduction of internal blinds on all windows in each of the analysed rooms. It is possible to see from the results that in general terms this measure individually produces better results than the introduction of night time cooling. No overheating risk has been identified in any of the 3 plots when tested against the current weather scenario. In the current weather scenario all rooms in all plots pass all three criteria of CIBSE TM52. Three bedrooms, in Plot 227 have shown a minor risk (fail two CIBSE TM52 criteria) of overheating on the 2030 weather case scenario. For the year 2050 only the kitchen in Plot 227 is showing a high risk of overheating. All other rooms in Plot 227 are at minor risk, which is in itself an improvement to the results from introducing only night time cooling. In the year 2050 Plot 120 is showing no overheating risks and in Plot 049 there is a mix of rooms at minor risk or no risk of overheating.

Combining the blinds and the night time cooling measures was not sufficient to completely eliminate the overheating risks in Plots 049 and 227 in the 2050 scenario. A third additional measure of increasing ventilation, which opened the windows fully and replaced some fixed panes into openable completely reduce the overheating in all the weather scenarios.

Table 5 - Results for Base Case scenario and single iterations

Scenario	Plot No._ Level_ Room	CURRENT					2030					2050				
		Criteria 1 (%Hrs Top-Tmax>=1K) (3%)	Criteria 2 (Max. Daily Deg.Hrs) (6º)	Criteria 3 (Max. DeltaT) (4ºK)	Criteria failing	Risk	Criteria 1 (%Hrs Top-Tmax>=1K) (3%)	Criteria 2 (Max. Daily Deg.Hrs) (6º)	Criteria 3 (Max. DeltaT) (4ºK)	Criteria failing	Risk	Criteria 1 (%Hrs Top-Tmax>=1K) (3%)	Criteria 2 (Max. Daily Deg.Hrs) (6º)	Criteria 3 (Max. DeltaT) (4ºK)	Criteria failing	Risk
Base Case	P049_GR_LV	0.5	6	1	-	No Risk	12.3	54	4	1 & 2	Minor	30.3	92	6	1 & 2 & 3	High
	P049_GR_Study	1.3	13	2	2	No Risk	14.5	58	4	1 & 2	Minor	31.7	106	6	1 & 2 & 3	High
	P049_GR_K	1.1	9	2	2	No Risk	15.5	40	4	1 & 2	Minor	31	87	7	1 & 2 & 3	High
	P049_L1_B1Master	5.6	38	3	1 & 2	Minor	35	93	5	1 & 2 & 3	High	49.7	135	7	1 & 2 & 3	High
	P049_L1_B2	1.7	18	2	2	No Risk	22.3	67	4	1 & 2	Minor	40.9	101	6	1 & 2 & 3	High
	P049_L1_B3	2.7	23	3	2	No Risk	29.1	75	6	1 & 2 & 3	High	46.7	109	7	1 & 2 & 3	High
	P049_L1_B4	7.1	38	4	1 & 2	Minor	40.9	89	6	1 & 2 & 3	High	53.3	124	8	1 & 2 & 3	High
	P049_L1_B5	5.9	33	4	1 & 2	Minor	34.9	87	6	1 & 2 & 3	High	50.4	120	8	1 & 2 & 3	High
	P120_GR_LV	0	1	1	-	No Risk	1	13	4	2	No Risk	3.5	46	5	1 & 2 & 3	High
	P120_GR_K	0	0	0	-	No Risk	1.1	15	3	2	No Risk	3.9	48	5	1 & 2 & 3	High
	P120_L1_B1	0	0	0	-	No Risk	2.9	16	2	2	No Risk	13.8	53	4	1 & 2	Minor
	P120_L1_B2	0.2	4	1	-	No Risk	6.8	29	3	1 & 2	Minor	20	71	6	1 & 2 & 3	High
	P120_L1_B3	0	1	1	-	No Risk	4.6	25	3	1 & 2	Minor	16	64	5	1 & 2 & 3	High
	P227_GR_LV	2.3	20	4	2	No Risk	82.2	200	11	1 & 2 & 3	High	87.4	250	13	1 & 2 & 3	High
	P227_GR_Dinning	2.7	22	4	2	No Risk	84.2	212	11	1 & 2 & 3	High	89.4	261	14	1 & 2 & 3	High
	P227_GR_Study	1.7	14	4	2	No Risk	46.3	131	10	1 & 2 & 3	High	58.9	184	12	1 & 2 & 3	High
	P227_GR_K	3.6	28	5	1 & 2 & 3	High	85.5	206	12	1 & 2 & 3	High	90.5	255	14	1 & 2 & 3	High
	P227_L1_B1 Master	18.4	90	6	1 & 2 & 3	High	65.5	158	9	1 & 2 & 3	High	73.4	199	11	1 & 2 & 3	High
	P227_L1_B2	31.2	91	7	1 & 2 & 3	High	88.1	192	12	1 & 2 & 3	High	91.5	225	13	1 & 2 & 3	High
	P227_L1_B3	36.4	105	6	1 & 2 & 3	High	89.8	210	10	1 & 2 & 3	High	96.1	247	12	1 & 2 & 3	High
	P227_L1_B4	37.8	110	8	1 & 2 & 3	High	90.1	202	12	1 & 2 & 3	High	95.3	241	14	1 & 2 & 3	High
	P227_L1_B5	41.1	120	7	1 & 2 & 3	High	90.4	211	11	1 & 2 & 3	High	97.2	251	13	1 & 2 & 3	High
Night Cooling	P049_GR_LV	0	0	0	-	No Risk	4.1	31	3	1 & 2	Minor	12.8	62	5	1 & 2 & 3	High
	P049_GR_Study	0	0	0	-	No Risk	6.5	42	3	1 & 2	Minor	16.9	83	5	1 & 2 & 3	High
	P049_GR_K	0	0	0	-	No Risk	7.5	25	4	1 & 2	Minor	18.1	68	6	1 & 2 & 3	High
	P049_L1_B1Master	0.3	6	1	-	No Risk	12.9	58	4	1 & 2	Minor	26.6	106	6	1 & 2 & 3	High
	P049_L1_B2	0	0	0	-	No Risk	11.4	47	4	1 & 2	Minor	27.6	78	5	1 & 2 & 3	High
	P049_L1_B3	0.2	3	1	-	No Risk	13.5	52	5	1 & 2 & 3	High	31.6	86	6	1 & 2 & 3	High
	P049_L1_B4	0.5	6	2	-	No Risk	18.8	62	5	1 & 2 & 3	High	36.2	95	7	1 & 2 & 3	High
	P049_L1_B5	0.7	6	2	-	No Risk	16.7	62	6	1 & 2 & 3	High	34	97	7	1 & 2 & 3	High
	P120_GR_LV	0	0	0	-	No Risk	0.9	13	4	2	No Risk	3.2	42	5	1 & 2 & 3	High
	P120_GR_K	0	0	0	-	No Risk	1	14	3	2	No Risk	3.5	44	5	1 & 2 & 3	High
	P120_L1_B1	0	0	0	-	No Risk	0.7	7	1	2	No Risk	5.9	36	4	1 & 2	Minor
	P120_L1_B2	0	0	0	-	No Risk	3.1	18	3	1 & 2	Minor	10.3	52	5	1 & 2 & 3	High
	P120_L1_B3	0	0	0	-	No Risk	2.1	15	2	2	No Risk	8.5	48	5	1 & 2 & 3	High
	P227_GR_LV	0.8	10	3	2	No Risk	12.1	47	5	1 & 2 & 3	High	23.4	112	7	1 & 2 & 3	High
	P227_GR_Dinning	1.1	14	4	2	No Risk	13.5	52	6	1 & 2 & 3	High	25	123	8	1 & 2 & 3	High
	P227_GR_Study	1.6	11	4	2	No Risk	9	54	7	1 & 2 & 3	High	17.8	99	9	1 & 2 & 3	High
	P227_GR_K	1.7	16	4	2	No Risk	16	58	6	1 & 2 & 3	High	28.6	123	9	1 & 2 & 3	High
	P227_L1_B1 Master	5.3	39	4	1 & 2	Minor	34.5	107	7	1 & 2 & 3	High	50.7	148	9	1 & 2 & 3	High
	P227_L1_B2	13.9	53	6	1 & 2 & 3	High	48.4	117	9	1 & 2 & 3	High	59	151	10	1 & 2 & 3	High
	P227_L1_B3	17.3	63	4	1 & 2	Minor	51.8	124	7	1 & 2 & 3	High	63.4	168	9	1 & 2 & 3	High
	P227_L1_B4	19.8	72	6	1 & 2 & 3	High	53.2	116	9	1 & 2 & 3	High	62.7	161	11	1 & 2 & 3	High
	P227_L1_B5	22.1	79	5	1 & 2 & 3	High	56.3	121	8	1 & 2 & 3	High	66.6	173	10	1 & 2 & 3	High
Blinds	P049_GR_LV	0	0	0	-	No Risk	0.2	6	1	-	No Risk	2	23	2	2	No Risk
	P049_GR_Study	0	0	0	-	No Risk	0.2	6	1	-	No Risk	1.9	29	2	2	No Risk
	P049_GR_K	0	0	0	-	No Risk	1.8	9	2	2	No Risk	8.3	32	4	1 & 2	Minor
	P049_L1_B1Master	0	0	0	-	No Risk	0.5	14	1	2	No Risk	4	32	2	1 & 2	Minor
	P049_L1_B2	0	0	0	-	No Risk	0	0	0	-	No Risk	1.5	20	2	2	No Risk
	P049_L1_B3	0	0	0	-	No Risk	0.2	6	1	-	No Risk	3.3	25	3	1 & 2	Minor
	P049_L1_B4	0	0	0	-	No Risk	0.6	9	1	2	No Risk	6.3	31	3	1 & 2	Minor
	P049_L1_B5	0	0	0	-	No Risk	0.6	9	2	2	No Risk	5.3	30	3	1 & 2	Minor
	P120_GR_LV	0	0	0	-	No Risk	0.4	7	4	2	No Risk	2.2	34	4	2	No Risk
	P120_GR_K	0	0	0	-	No Risk	0.5	9	2	2	No Risk	2.5	37	4	2	No Risk
	P120_L1_B1	0	0	0	-	No Risk	0	0	0	-	No Risk	0.7	17	2	2	No Risk
	P120_L1_B2	0	0	0	-	No Risk	0	1	1	-	No Risk	1.7	26	3	2	No Risk
	P120_L1_B3	0	0	0	-	No Risk	0	0	0	-	No Risk	1.2	24	3	2	No Risk
	P227_GR_LV	0	0	0	-	No Risk	0.7	12	2	2	No Risk	3.8	43	4	1 & 2	Minor
	P227_GR_Dinning	0	0	0	-	No Risk	1.1	16	2	2	No Risk	4.9	46	4	1 & 2	Minor
	P227_GR_Study	0	0	0	-	No Risk	0.7	8	2	2	No Risk	3.6	33	4	1 & 2	Minor
	P227_GR_K	0	1	1	-	No Risk	1.3	16	3	2	No Risk	6	48	5	1 & 2 & 3	High
	P227_L1_B1 Master	0	0	0	-	No Risk	0.7	14	1	2	No Risk	6.2	36	3	1 & 2	Minor
	P227_L1_B2	0	0	0	-	No Risk	3	19	3	1 & 2	Minor	14.8	49	4	1 & 2	Minor
	P227_L1_B3	0	0	0	-	No Risk	3.7	27	2	1 & 2	Minor	17.7	57	4	1 & 2	Minor
	P227_L1_B4	0.4	3	1	-	No Risk	4	26	3	1 & 2	Minor	17.3	55	4	1 & 2	Minor
	P227_L1_B5	0.1	2	1	-	No Risk	3.9	27	3	1 & 2	Minor	18.4	60	4	1 & 2	Minor

Table 6 - Results for combined iterations

Scenario	Plot No._ Level_ Room	CURRENT					2030					2050				
		Criteria 1 (%Hrs Top-Tmax>=1K) (3%)	Criteria 2 (Max. Daily Deg.Hrs) (6º)	Criteria 3 (Max. DeltaT) (4ºK)	Criteria failing	Risk	Criteria 1 (%Hrs Top-Tmax>=1K) (3%)	Criteria 2 (Max. Daily Deg.Hrs) (6º)	Criteria 3 (Max. DeltaT) (4ºK)	Criteria failing	Risk	Criteria 1 (%Hrs Top-Tmax>=1K) (3%)	Criteria 2 (Max. Daily Deg.Hrs) (6º)	Criteria 3 (Max. DeltaT) (4ºK)	Criteria failing	Risk
Blinds and Night cooling	P049_GR_LV	0	0	0	-	No Risk	0	0	0	-	No Risk	0.9	15	2	2	No Risk
	P049_GR_Study	0	0	0	-	No Risk	0	0	0	-	No Risk	1	21	2	2	No Risk
	P049_GR_K	0	0	0	-	No Risk	0.8	5	2	-	No Risk	5	27	4	1 & 2	Minor
	P049_L1_B1 Master	0	0	0	-	No Risk	0	0	0	-	No Risk	0.8	23	2	2	No Risk
	P049_L1_B2	0	0	0	-	No Risk	0	0	0	-	No Risk	0.4	9	1	2	No Risk
	P049_L1_B3	0	0	0	-	No Risk	0.1	2	1	-	No Risk	1.1	16	2	2	No Risk
	P049_L1_B4	0	0	0	-	No Risk	0.1	4	1	-	No Risk	1.5	19	2	2	No Risk
	P049_L1_B5	0	0	0	-	No Risk	0.1	4	1	-	No Risk	1.7	20	2	2	No Risk
	P120_GR_LV	0	0	0	-	No Risk	0.4	7	4	2	No Risk	2	33	4	2	No Risk
	P120_GR_K	0	0	0	-	No Risk	0.5	8	2	2	No Risk	2.3	35	4	2	No Risk
	P120_L1_B1	0	0	0	-	No Risk	0	0	0	-	No Risk	0.5	16	2	2	No Risk
	P120_L1_B2	0	0	0	-	No Risk	0	0	0	-	No Risk	0.9	22	3	2	No Risk
	P120_L1_B3	0	0	0	-	No Risk	0	0	0	-	No Risk	0.8	18	2	2	No Risk
	P227_GR_LV	0	0	0	-	No Risk	0.4	8	2	2	No Risk	2.8	37	4	2	No Risk
	P227_GR_Dinning	0	0	0	-	No Risk	0.7	11	2	2	No Risk	3.6	41	4	1 & 2	Minor
	P227_GR_Study	0	0	0	-	No Risk	0.4	6	2	-	No Risk	2.7	30	4	2	No Risk
	P227_GR_K	0	0	0	-	No Risk	0.9	10	2	2	No Risk	4.3	38	5	1 & 2 & 3	High
	P227_L1_B1 Master	0	0	0	-	No Risk	0.3	7	1	2	No Risk	3.6	31	2	1 & 2	Minor
	P227_L1_B2	0	0	0	-	No Risk	1.5	13	2	2	No Risk	7.6	34	4	1 & 2	Minor
	P227_L1_B3	0	0	0	-	No Risk	1.8	18	2	2	No Risk	9.3	43	3	1 & 2	Minor
	P227_L1_B4	0	0	0	-	No Risk	2	17	2	2	No Risk	9.4	39	4	1 & 2	Minor
	P227_L1_B5	0	0	0	-	No Risk	1.9	20	2	2	No Risk	10.5	46	4	1 & 2	Minor
Blinds, Night cooling and ventilation increased (P227)	P049_GR_LV	0	0	0	-	No Risk	0	0	0	-	No Risk	0.2	5	3	-	No Risk
	P049_GR_Study	0	0	0	-	No Risk	0	0	0	-	No Risk	0.2	4	1	-	No Risk
	P049_GR_K	0	0	0	-	No Risk	0	0	0	-	No Risk	0.6	8	2	2	No Risk
	P049_L1_B1 Master	0	0	0	-	No Risk	0	0	0	-	No Risk	0.1	3	1	-	No Risk
	P049_L1_B2	0	0	0	-	No Risk	0	0	0	-	No Risk	0.1	2	1	-	No Risk
	P049_L1_B3	0	0	0	-	No Risk	0	0	0	-	No Risk	0.1	3	1	-	No Risk
	P049_L1_B4	0	0	0	-	No Risk	0	0	0	-	No Risk	0.1	4	1	-	No Risk
	P049_L1_B5	0	0	0	-	No Risk	0	0	0	-	No Risk	0.2	6	1	-	No Risk
	P120_GR_LV	0	0	0	-	No Risk	0.4	7	4	2	No Risk	2	33	4	2	No Risk
	P120_GR_K	0	0	0	-	No Risk	0.5	8	2	2	No Risk	2.3	35	4	2	No Risk
	P120_L1_B1	0	0	0	-	No Risk	0	0	0	-	No Risk	0.5	16	2	2	No Risk
	P120_L1_B2	0	0	0	-	No Risk	0	0	0	-	No Risk	0.9	22	3	2	No Risk
	P120_L1_B3	0	0	0	-	No Risk	0	0	0	-	No Risk	0.8	18	2	2	No Risk
	P227_GR_LV	0	0	0	-	No Risk	0.1	2	1	-	No Risk	1	21	3	2	No Risk
	P227_GR_Dinning	0	0	0	-	No Risk	0.1	2	1	-	No Risk	1.3	28	3	2	No Risk
	P227_GR_Study	0	0	0	-	No Risk	0.1	3	1	-	No Risk	1.8	21	3	2	No Risk
	P227_GR_K	0	0	0	-	No Risk	0.2	3	1	-	No Risk	1.5	22	4	2	No Risk
	P227_L1_B1 Master	0	0	0	-	No Risk	0	1	1	-	No Risk	2	24	2	2	No Risk
	P227_L1_B2	0	0	0	-	No Risk	0.1	4	1	-	No Risk	1.3	17	3	2	No Risk
	P227_L1_B3	0	0	0	-	No Risk	0	0	0	-	No Risk	1.1	21	2	2	No Risk
	P227_L1_B4	0	0	0	-	No Risk	0.2	5	1	-	No Risk	1.6	20	3	2	No Risk
	P227_L1_B5	0	0	0	-	No Risk	0.1	4	1	-	No Risk	1.6	21	2	2	No Risk

7 CONCLUSIONS

7.1 The Development Consultancy team at PRP was appointed by Crest Nicholson to carry out an overheating analysis on the worst case scenario houses in Phases 3 and 4 of the Bicester development, in Oxfordshire. 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'.

7.2 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 Phases 3 and 4 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 two more future weather projections (2030 and 2050).

7.3 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.

7.4 The houses within Phases 3 and 4 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, it is possible that they will face a risk of overheating, especially when assessed under future weather data (2030 and 2050).

7.5 The current analysis is focused on three units within Phases 3 and 4 of Bicester Eco Town, which were considered the worst performing out of the units that were subject to design changes:

- **Private House 49** - 5 bedrooms
- **Private House 120** - 3 bedrooms
- **Private House 227**- 5 bedrooms

7.6 From the results presented in Chapter 6 above, it is possible to conclude that the blinds are more effective as a standalone mitigation measure than the introduction of night time cooling, as they contribute more to the reduction of overheating risk than the night time cooling measure. Plot 227 seems to be the dwelling more affected by overheating and Plot 120 the dwelling less affected (out of the 3 dwellings tested).

7.7 The introduction of both mitigation measures: blinds and night time cooling, seem to completely eliminate (for all Plots), the occurrence of high or minor overheating risk for both the current and 2030 weather scenarios.

7.8 When analysing the results for the 2050 weather scenario it was possible to conclude that the combined use blinds, night time cooling and increased of ventilation (plot 227) is sufficient to eliminate the risk of overheating in all plots.

7.9 It should also be noted that in order to be consistent with the existing overheating analysis of Phases 3 and 4, 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.

7.10 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.

8 REFERENCES

- Zero Carbon Hub and NHBC Foundation: CARBON COMPLIANCE FOR TOMORROW'S NEW HOMES. A REVIEW OF THE MODELLING TOOL AND ASSUMPTIONS. TOPIC 3: FUTURE CLIMATE CHANGE. August 2010
- Communities and Local Government: Planning Policy Statement: eco-towns. A supplement to Planning Policy Statement 1. July 2009 ISBN: 978-1-4098-1683-6
- Prometheus Weather files by the University of Exeter.

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 temepraturе; 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 latent 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:

$$\Delta T = T_{op} - T_{max}$$

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 $\Delta T \leq 0$, 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:

$$W_e = \frac{1}{2} [(10 \times 0) + (3 \times 1) + (2 \times 2) + (1 \times 3)]$$

= 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 Previous overheating criteria - CIBSE GUIDE A (2006)

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