Residential Overheating Risk

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PROJECT:

Greenwood Place
19-37 Highgate Road
London
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Contents

Executive Summary

Hilson Moran was appointed by Fortnum Developments (the Applicant) to provide an Energy Strategy for the proposed development at 19 – 37 Highgate Road and the neighbouring A&A Self Storage unit. Proposals for the Site comprise a mixed development with residential units, offices and relocation of the self-storage provision to below ground.

The purpose of this report is to identify overheating risks for the residential elements of the proposed development, specifically to the requirements of CIBSE TM52 and in line with the Greater London Authority (GLA) 'Energy Planning' guide update, April 2015.

Dynamic thermal modelling is used to assess the risk of overheating and forms part of a cooling hierarchy design approach as recommended by the current GLA policy.

This analysis concludes that the natural ventilation strategy and a window glass g-value limited to 0.4 contribute to eliminating the risk of overheating in most apartments.

Building 1 observations:

The overheating analysis of Building 1 results in the following findings:

- All bedrooms in Building 1 pass the CIBSE TM52 Overheating criteria;
- All living rooms from ground floors to floor 7 pass the CIBSE TM52 Overheating criteria;
- One south-west facing living rooms on the top floor, in the flat number 1.8.2, presents a risk of overheating **for a maximum of 1 day per year**.

Comfort cooling is proposed in the top floor flats of Building 1 to mitigate the identified risk of overheating.

Building 2 observations:

The overheating analysis of Building 2 results in the following findings:

- All bedrooms in Building 2 pass the CIBSE TM52 Overheating criteria;
- All living rooms from ground floors to floor 4 and on the top floor pass the CIBSE TM52 Overheating criteria;
- One south-west facing living rooms on floor 5, in the flat number 2.5.4, presents a risk of overheating **for a maximum of 2 days per year**.

For this particular dwelling, additional measures are recommended to help limit the overheating risk, these include:

- Installation of external blinds or external shading to terrace openings;
- Increasing the proportion of openable glazed areas to provide a higher level of natural ventilation;
- Considering use of ceiling fans to increase air movement in the dwelling; and
- Considering a high level of thermal mass surfaces in living rooms to reduce peak temperatures.

1. Introduction

1.1. Background and project description

Hilson Moran has been commissioned by Fortnum Developments (the Applicant) to carry out an overheating risk analysis for the proposed development on Greenwood Place, 17-37 Highgate Road, in the London Borough of Camden.

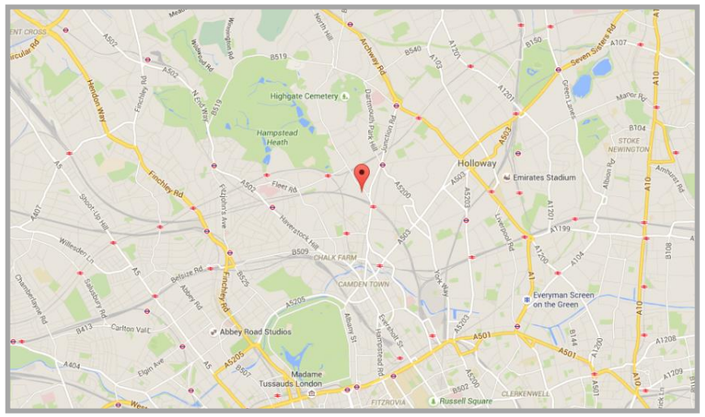

Figure 1: *Location of proposed development*

The development consists of 2 mixed use buildings:

- Building 1: a 8 storey building which includes car park, communal storage area, retail use, office spaces and dwellings; and
- Building 2: a 6 storey building which includes cafe area, communal storage area and dwellings on 6 floors.

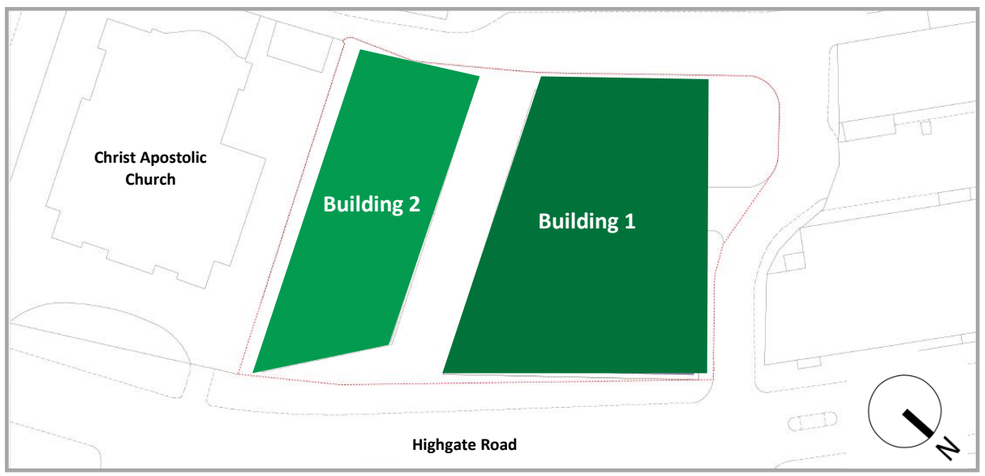

Figure 2: *Indicative mass plan for the proposed Greenwood development*

Figure 3: *Indicative mass elevation for the proposed Greenwood development*

1.2. Related reports

This report should be read in conjunction with the following reports that are submitted as part of the planning application:

- Energy Strategy
- Sustainability Statement

1.3. Scope

This report relates to the residential elements of the proposed development and is based on drawings issued by Squire and Partners on the 01/12/2015.

1.4. Purpose

The purpose of the report is to identify overheating risks for the residential elements of the proposed development, specifically against the requirements of CIBSE Guide A and CIBSE TM52, in accordance with the GLA 'Energy Planning' guide update of April 2015.

1.5. Structure

Section 2 is a brief summary of planning requirements for overheating risk analysis, followed by a summary of CIBSE Guide A, BS EN 15251:2007, CIBSE TM49 and TM 52 criteria. Methodologies are described in section 3. Section 4 sets out the approach applied for the risk analysis, Section 5 describes the explored and implemented measures in the context of the GLA's Cooling Hierarchy approach and Section 6 lists the input of the dynamic thermal model, including building fabric and glazing specifications, system specifications, internal gains and assumed occupancy patterns and behaviour. Section 7 and 8 presents the results of the analysis and Section 9 includes conclusions and recommendations.

2. GLA Overheating Policy and Guidance

2.1. The London Plan

On 10 March 2015, the Mayor adopted the Further Alterations to the London Plan (FALP).

Chapter 5 'London's Response to Climate Change' requires that all developments:

> *"make the fullest contribution to London's adaptation to climate change and should be designed for the warmer, wetter winters and hotter, drier summers the city will experience over their lifetime, and to withstand possible natural hazards (such as heat waves, flooding and droughts) that may occur."*

Paragraph 5.9 'Overheating and cooling' states the following:

Strategic

1. The Mayor seeks to reduce the impact of the urban heat island effect in London and encourages the design of places and spaces to avoid overheating and excessive heat generation, and to reduce overheating due to the impacts of climate change and the urban heat island effect on an area wide basis.

Planning decisions

2. Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the following cooling hierarchy:
    1. Minimise internal heat generation through energy efficient design
    2. Reduce the amount of heat entering a building in summer through orientation, shading, albedo, fenestration, insulation and green roofs and walls
    3. Manage the heat within the building through exposed internal thermal mass and high ceilings
    4. Passive ventilation
    5. Mechanical ventilation
    6. Active cooling systems (ensuring they are the lowest carbon options).
3. Major development proposals should demonstrate how the design, materials, construction and operation of the development would minimise overheating and also meet its cooling needs. New development in London should also be designed to avoid the need for energy intensive air conditioning systems as much as possible. Further details and guidance regarding overheating and cooling are outlined in the London Climate Change Adaptation Strategy.

LDF[1] preparation

4. Within LDFs boroughs should develop more detailed policies and proposals to support the avoidance of overheating and to support the cooling hierarchy.

2.2. Energy Planning

The Greater London Authority's guidance on preparing energy assessment, Energy Planning, was updated in April 2015. The update clarifies the information required to demonstrate that overheating risk has been properly considered and that the demand for cooling has been minimised (London Plan Policy 5.9 above).

In addition to the cooling hierarchy approach (described in the Energy Strategy report of the planning application), the new guidance requires that:

1. Part L requirements to limit the effect of heat gains in summer are complied with. Developers should demonstrate this using the SAP[2] (residential) or SBEM[3] (non-residential) basic overheating compliance test.

These are reported in the Energy Strategy and the Part L1A:2013 Assessment reports submitted as part of the planning application.

"However, the regulations explicitly recognise that, as the test does not cover all factors influencing overheating, there is no guarantee that buildings will not overheat and developers should carry out additional design assessments."

2. For this reason the GLA also encourages developers to undertake dynamic modelling to assess the risk of overheating in their development. Energy Planning refers to section 3.2.4 of the Sustainable Design and Construction SPG for guidance on minimising the requirement for active cooling.

Where dynamic modelling is carried out, it should be undertaken in accordance with the guidance and data sets in CIBSE TM49 'Design Summer Years for London'. This guide aims to provide a risk-based approach to help developers and their advisers simultaneously address the challenges of developing in an urban heat island and managing an uncertain future climate, which are summarised in the following section.

CIBSE guide TM52, 'The Limits of Thermal Comfort: Avoiding Overheating in European Buildings', contains additional guidance on the limits of thermal comfort.

Where design measures and the use of natural and/or mechanical ventilation are not enough to guarantee the occupant's comfort (in line with the cooling hierarchy set out in London Plan Policy 5.9), the developer should identify the cooling requirement of the different elements of the development in the energy assessment document.

[1] LDF: London Development Frameworks

[2] SAP: Standard Assessment Procedure
[3] SBEM: Simplified Building Energy Model

3. Industry Overheating Risk Guidance

This section summarises the key information from the relevant guidance used to assess the risk of overheating for the Greenwood Place development.

3.1. Operative Temperature

The principal metric for thermal comfort is specified based on operative temperature (t_o), which is an expression of the temperature you experience or feel. The operative temperature can be expressed as a function of air temperature (t_a), radiant temperature (t_r) and air speed (v) and CIBSE suggests the following formula (CIBSE 2015 (ref)):

$$t_o = \frac{t_a\sqrt{(10v)} + t_r}{1+\sqrt{(10v)}}$$

3.2. CIBSE Guide A: Environmental Design (2015) and BS EN 15251:2007

For naturally ventilated buildings, BS EN 15251:2007[4] specifies indoor environmental parameters which have an impact on the energy performance of buildings. The CIBSE Guide A (2015) recommendations for testing for the presence or likelihood of overheating follows the methodology and recommendations of BS EN 15251 (2007).

The method used in the BS to define overheating in buildings sets acceptable temperature ranges for naturally ventilated buildings based on the sensitivity of occupants and their comfort expectation.

Expectation levels are set out in the following categories:

- Category I: High level of expectation (only used for spaces occupied by very sensitive and fragile persons)
- Category II: Normal expectation (for new buildings and renovations)
- Category III: Moderate expectation (used for existing buildings)

This report assesses the proposed development against Category II criteria.

3.2.1. **Naturally ventilated buildings**

For naturally ventilated buildings the designer should aim for an indoor operative temperature close to that calculated from the running mean of the outdoor temperature according to the following equation:

$$t_{com} = 0.33\ t_{rm} + 18.8$$

Where t_{com} is the comfort operative temperature and t_{rm} is the running mean outdoor air temperature.

The upper limit conditions for avoiding overheating, t_{max}, in a Category II expectation level is represented by the following formula:

$$t_{max} = t_{com} + 3$$

CIBSE TM52 sets three criteria by which a building can be classed as overheating as described below.

It should be noted that, according to BS EN 15251, it is possible to increase comfort temperature upper limits if the operative temperature is higher than 25°C and internal air speed is higher than 0.1 m/s, through the use of personal fans for example.

3.2.2. **Testing by simulation**

Where dynamic thermal modelling is used to assess overheating risk, realistic algorithms for occupant behaviour, the use of windows and other adaptive behaviour should be used and a realistic occupancy schedule is necessary.

3.2.1. **Air-conditioned buildings**

CIBSE Guide A recommends that a mechanically cooled building should aim to provide an indoor environment where the Predicted Mean Vote (PMV, see section 3.6 below) index as near to or equal to zero. It will be considered as overheating if the value of the PMV index in above 0.5 (equivalent to a Predicted People Dissatisfied, PPD, of 10%).

Where the PMV is unavailable, maximum operative temperatures are provided for various types of spaces and metabolic rates, assuming a clothing insulation of 1.0 for winter and 0.5 for summer (CIBSE Guide A, Table 1.8). The recommended operative temperatures in living rooms are 25.0°C in summer 23.0°C in winter assuming an activity level met of 1.2. For more active uses and a met activity level of 1.5, the recommended maximum temperature for winter overheating is lowered to 22°C.

The predicted indoor values of PMV should not exceed 0.5, or said operative temperature should not be exceeded, for more that 3% of occupied hours. For summer conditions simulations should be made using design summer years.

Note that winter overheating criteria also apply to naturally ventilated buildings that are heated.

3.3. CIBSE guide TM52: The Limits of Thermal Comfort: Avoiding Overheating in European Buildings (2013)

CIBSE TM52 entitled 'The Limits of Thermal Comfort: Avoiding Overheating in European Buildings', provides guidance on predicting overheating in buildings. It is intended to inform designers, developers and others responsible for defining the indoor environment in buildings and it is recommended that this is considered when carrying out modelling.

TM52 sets three criteria by which a building can be classed as overheating:

1. **Hours of exceedance**: The operative temperature t_{max} is not exceeded by 1 Kelvin(K) for more than 3% of occupied hours during a typical non-heating season (1st May – 30th September)
2. **Upper limit temperature**: Sets an absolute maximum acceptable daily temperature for the room, beyond which the level of overheating is unacceptable (4K higher than maximum acceptable temperature)
3. **Daily weighted exceedance**: Sets a daily limit for acceptability for temperature rise and duration.

A room or building that fails any two of the three criteria is classed as overheating.

[4] BS EN 15251:2007: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (BSI, 2007)

3.4. CIBSE guide TM49: Design Summer Years for London (2014)

CIBSE guidance TM49 and the accompanied Design Summer Years for London enable designers to analyse the summer performance of their buildings and investigate the impact of urban macroclimatic factors and climate change when carrying out overheating risk assessments for buildings in London.

As it is impossible to prejudge the impact of warm weather conditions on a building in a general sense, overheating modelling can be conducted using the following three design weather years:

- 1976: a year with a prolonged period of sustained warmth
- 1989: a moderately warm summer (current design year for London)
- 2003: a year with a very intense single warm spell

To enable the urban heat island effect in the locality of the development to be taken into account, weather year data for three different locations are provided in the guide. The most representative weather data set for the project location should be used. For development within:

- The Greater London Authority Central Activity Zone (CAZ) and other high density urban areas: London Weather Centre data.
- Lower density urban and suburban areas: London Heathrow airport data.
- Rural and peri-urban areas around the edge of London: Gatwick Airport data.

3.5. Predicted Mean Vote & Percentage People Dissatisfied (PMV &PPD)

PMV and PPD are thermal comfort metrics calculated according to the methodology set out in ISO7730 (Ergonomics of the thermal environment).

PMV combines the influences of air temperature, mean radiant temperature, air speed and humidity with that of clothing and activity level into a 7 point thermal sensation scale ranging from -3 (Cold) to +3 (Hot) with zero being neutral/comfortable.

PPD reflects that people have different tolerances/preferences to their thermal environment and it will not normally be possible to satisfy everyone at the same time. Results will be scattered around the predicted mean value (i.e. PMV) and PPD looks at the probability that a person selected at random (from a hypothetical large group) is likely to be dissatisfied.

4. Methodology applied

4.1. Cooling Hierarchy

The design was developed in line with the GLA's 'Cooling Hierarchy' approach, which recommends consideration of lean measures first to reduce the cooling demand (reducing heat gain and passive design measures) before applying measures that consume energy to achieve internal comfort conditions. This approach aims to reduce the overall CO_2 emissions from cooling and consists of the following steps:

A. **Minimisation of internal heat generation through energy efficient design**
B. **Reduction of the amount of heat entering the building in summer**
C. **Management of the heat within the building through exposed thermal mass and high ceilings**
D. **Passive ventilation**
E. **Mechanical cooling**
F. **Active cooling**

Section 5 describes the measures explored and implemented in the proposed design.

4.2. Assessment criteria

The following methodology has been applied to the Greenwood Place development overheating assessment.

In each building the three top floors are tested, because they represent the most exposed levels of the building and, therefore, a worst case scenario.

Floors 6, 7 and 8 in Building 1 and floors 4, 5 and 6 in Building 2 are tested.

Living rooms and bedrooms, as the main occupied zones in all apartments on these floors, are assessed using the following four weather files in line with CIBSE TM 49 and TM52:

- **Baseline: CIBSE Design Summer Year (London DSY)**
- **Test 1: A year with a prolonged period of sustained warmth**
- **Test 2: A moderately warm summer (current design year for London)**
- **Test 3: A : A year with a very intense single warm spell**

Thermal modelling is carried out using software in accordance with CIBSE AM11 Building Energy and Environmental Modelling.

4.2.1. Natural ventilation

The first step of the assessment looks at the potential for the rooms in the baseline test to overcome overheating risk using natural ventilation only, for the weather files above.

Table 1 summarises the criteria adopted for assessing potential for natural ventilation to overcome the risk of overheating in the proposed building.

Test	Assessment criteria		Acceptable deviation	Investigated period	Weather file
Baseline and future overheating risk (CIBSE TM52, 2013 and BS EN 15251:2007)	Criterion 1	The frequency of the time when operative temperature is higher than maximum acceptable temperature	3% of occupied hours	May-September	CIBSE London DTM + TM49 Design Summer Years for London
	Criterion 2	A daily limit for acceptability for temperature rise and duration is not exceeded	6°hrs a day	May-September	
	Criterion 3	An absolute operative temperature for the room is not exceeded 4K higher than maximum acceptable temperature		May-September	

Table 1: *Assessment criteria for naturally ventilated buildings*

The following natural ventilation scenarios were tested:

- **The model assumes that windows partially open during dwelling occupied hours when the internal temperature[5] exceeds 22°C and are fully open when the internal temperature reaches 25°C (all weather files above)**

The approach used to assess for overheating risk is the one recommended by CIBSE guide TM52 applying three overheating criteria checks (see section 3.5 above), namely:

1. **Criterion 1: Hours of exceedance**
2. **Criterion 2: Daily weighted exceedance**
3. **Criterion 3: Upper limit temperature**

The rooms are assessed against expectancy Category II of BS EN 15251:2007, i.e. 'Normal expectation' (recommended for new buildings and renovations). A room that fails any two of the three TM 52 criteria is classed as overheating.

[5] Operative temperature

4.2.2. **Air-conditioning**

Where passive design measures and natural ventilation are insufficient to mitigate the risk of overheating, a thermal comfort analysis is carried out to demonstrate that comfort conditions are achieved for an air-conditioned building.

For this analysis the following assessment criteria are applied in accordance with CIBSE Guide A recommendations:

- **The building is analysed using design summer years (DSY)**
- **The PMV index should not exceed 0.5 (equivalent to a PPD of 10%) for more than 3% of annual occupied hours**
- **Where the PMV index is not available, the operative temperature must not exceed 26.0°C in summer assuming a clo level of 0.5 and 24.0°C in winter with a clo level of 1.0 (activity level met = 1.2[6]) for more than 3% of occupied hours.**

3% equates to a maximum of 87 hours per year for this analysis.

[6] For more active uses and a met activity level of 1.5, the recommended maximum temperature for winter overheating is lowered to 22°C.

5. Cooling Hierarchy

In line with the GLA's recommended Cooling Hierarchy approach, early design recommendations were provided to the project architect, Squire and Partners, and preliminary design test SAP assessments were carried out to enable a best practice approach to energy and CO_2 emissions reduction. The following summarises the design team's approach with respect to the cooling hierarchy.

Further details about measures applied are included in section 6 of this report and are shown in Figure 2.

A. Minimisation of internal heat generation through energy efficient design

- Heat gain from lighting will be kept to a minimum as a result of an energy-efficient lighting design solution.
- The availability of natural light is maximised to discourage the use of artificial lighting by optimising the light transmittance of the glass elements of the façade.
- Heat gains from domestic appliances and equipment can be influenced by low energy recommendations provided in a Home User Guide for residents.

B. Reduction of the amount of heat entering the building in summer

- Living areas are shaded by balconies that are inset from the external plane of the façade.
- All representative dwellings are anticipated to comply with the Part L1A Overheating criteria.
- The dynamic thermal modelling carried out has helped to optimise the g-value of glass relative to the light transmittance.

C. Management of the heat within the building through exposed thermal mass and high ceilings

- A medium level of internal thermal mass surfaces was assumed for the residential element of the proposed development.

D. Passive ventilation

- Residential windows are openable, providing occupant-controlled natural ventilation to the dwellings. Balcony doors offer a large ventilation area for the living spaces.
- The potential for natural ventilation to overcome the risk of overheating was assessed in accordance with CIBSE Guide A, CIBSE TM52, 2013 and BS EN 15251:2007, as described in the previous section. The results of this analysis are reported in section 7 and 8 of this report.

E. Mechanical cooling

- Mechanical ventilation with heat recovery is specified for the building, with summer bypass. This system is currently specified for fresh air provision only.

F. Active cooling

- Air conditioning was specified in order to overcome the risk of overheating in extreme circumstances to most exposed floors on the top storey (floor 8 in Building 1 and floor 6 in Building 2).
- The cooling demand for the proposed building relative to the Part L notional building is as follows:

	Cooling requirement (as in Part L1A)	
	Actual	Notional
Residential element (kWh/m²)	0.63	0

Table 2: *Cooling requirement for the cooled area of the residential elements*

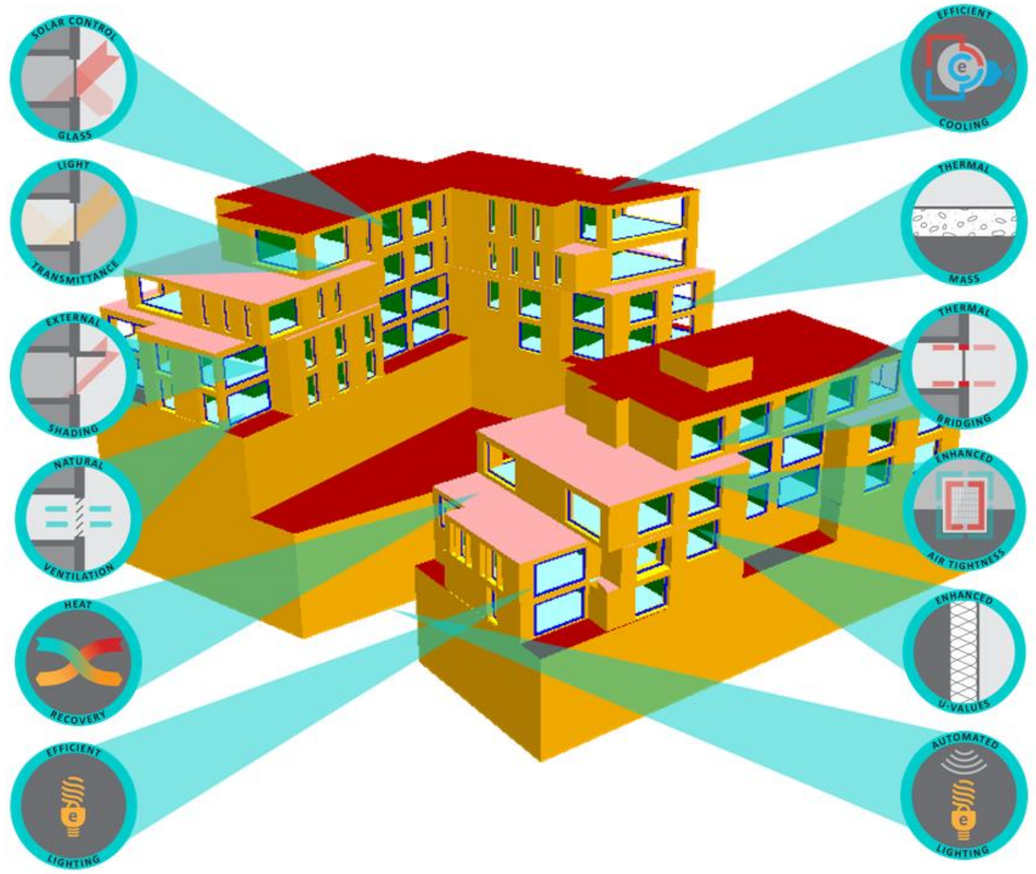

Figure 4: *Indication energy efficiency measures that are incorporated in the proposed development, shown on the dynamic thermal model*

6. Basis for Model

Dynamic Thermal Modelling (DTM) software tracks the thermal state of the building on an hourly basis using real weather data, resulting in a detailed picture of the building's performance.

DTM combines several mechanisms to calculate the building response:

- Conduction;
- Convection;
- Long wave radiation;
- Short wave radiation – absorbed, reflected and transmitted;
- Internal conditions – gains from lights, equipment and occupants along with plant operating hours and natural infiltration rates;
- Ventilation and air movement from internal natural convection.

The accredited software EDSL TAS version 9.3.3 was used for this assessment. This software tool is fully compliant with the CIBSE Applications Manual 11: Building Energy and Environment Modelling.

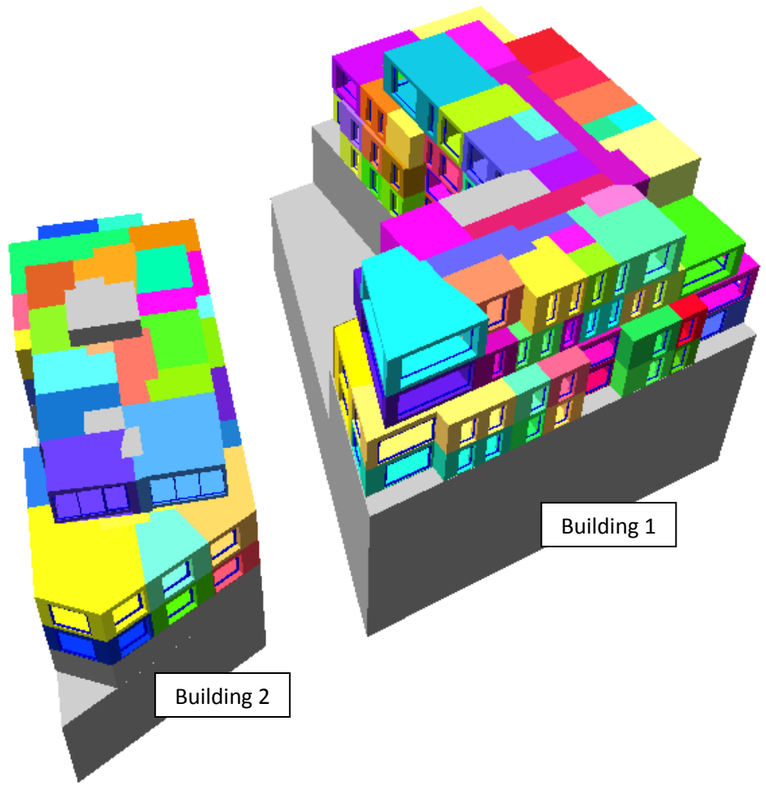

Figure 5: *Dynamic Thermal Model showing zoned floors 4, 5, 6, 7 and 8 (note that external brise-soleil and architectural shading does not appear in 3D illustration)*

The floors with the greatest exposed area have been tested in order to represent a worst case scenario. The analysis comprised of the following testing:

- Building 1 – All apartments (living rooms and bedrooms) on floors 6, 7 and 8
- Building 2 – All apartments (living rooms and bedrooms) on floors 4, 5 and 6

Level 5 in Building 1 and level 3 in Building 2 are also zoned in the model in order to ensure that fabric heat transfer does not unreasonably influence results.

Plans from the dynamic thermal model are included in Appendix A of this report.

6.1. Weather Data

The baseline test was run using the CIBSE London DSY (design summer year) weather file. This choice of DSY weather file reflects the hotter summers in recent years and is representative of more testing weather conditions when looking at thermal comfort.

The analysis tests the building in accordance with the guidance and data sets in CIBSE TM49 'Design Summer Years for London'. The guide aims to provide a risk-based approach to help developers and their advisers simultaneously address the challenges of developing in an urban heat island and managing an uncertain future climate, as summarised in the previous section.

The following three TM49 files where applied in addition to the CIBSE London DSY weather file:

- Test 1: 1976 - A year with a prolonged period of sustained warmth
- Test 2: 1989 - A moderately warm summer (current design year for London)
- Test 3: 2003 - A year with a very intense single warm spell

Weather files from the London Weather Centre data representing the Greater London Authority Central Activity Zone (CAZ) and other high density urban areas were used for this analysis.

6.2. Fabric

The proposed design incorporates a number of passive design measures, in order to reduce the energy demand and associated CO_2 emissions of the development. Note that in order to comply with Building Regulations Part L1A:2013 criteria and planning CO_2 emissions reduction targets, measures are primarily focussed on the control of heat loss.

The following viable fabric measures will be incorporated into the development:

- Optimised U-values for both opaque and transparent elements;
- Low thermal bridging;
- Optimised levels of air tightness;
- A medium level of internal thermal mass surfaces (as defined in SAP calculations);
- Natural ventilation through openable windows;
- Optimised transmittance glazing in façade;
- Solar control glazing within the façade, balancing passive solar control versus overheating for the residential elements and controlling thermal comfort on the commercial floors;
- External shading created by balconies;

The following table summarises minimum requirements, reference values and proposed characteristics of fabric performance parameters for the Greenwood Place development:

Element	Minimum requirement, Part L1A 2013	SAP2012 Appendix R: Reference values	Proposed Fabric / System performance
FABRIC			
External walls	0.30 W/m²K	0.18 W/m²K	0.15 W/m²K
Communal wall	0 W/m²K Heated Corridors	0 W/m²K Heated Corridors	0 W/m²K Heated Corridors
Windows	2.00 W/m²K	1.50 W/m²K g-value: 0.63	1.30 W/m²K g-value: 0.40
Roof U-value	0.20 W/m²K	0.13 W/m²K	0.13 W/m²K
Floor U-value	0.25 W/m²K	0.13 W/m²K	0.20 W/m²K
Air permeability	10.0 m³/h.m² @ 50 Pa	5.0 m³/m²/hr @ 50pa	3.0 m³/m²/hr @ 50pa
Thermal bridging	-	y = 0.05 W/m²K	Thermal bridging calculation (Accredited Construction Details)

Table 3: *SAP 2012 fabric parameters and values used for the Greenwood Place residential component*

6.3. Façade Specification

The following glass types have been used for the purpose of this study. The properties are typical of high performance solar control double glazing unit and similar glass types will be available from other manufacturers.

Glass Type	Centre Pane U-Value (W/m².K)	g-value	Light Transmittance
Sun Guard Super Neutral 62	1.0	0.40	70%

Table 4: *Windows parameters for the Greenwood Place residential component*

Note that the glazing g-value and light transmission that are listed here are only indicative and may vary for different products. As the performance between different glass manufacturers varies slightly, before final selection the 'preferred' glass should be tested to ensure it can meet the thermal comfort targets.

6.4. Shading

The buildings incorporate the architectural shading, and no other shading system is proposed.

The surrounding buildings have not been modelled in order to represent the worst case scenario for the proposed building. No significantly high building has been identified in the surrounding of the proposed development.

6.5. Systems

After energy demand reduction through passive measures, regulated energy consumption from building services has been minimised through the specification of energy efficient systems.

The energy performance of building services is required to comply with building regulations efficiency criteria[7] and should exceed performance levels applied in the notional building wherever possible. Measures include:

- Energy efficient lighting systems;
- Presence detection on lighting controls in common areas;
- Heat recovery integrated into ventilation systems in the residential units and common areas, where applicable.

The following system performance efficiencies will be specified for the Greenwood Place development:

Element	Minimum requirement, Part L1A 2013	SAP2012 Appendix R: Reference values	Proposed Fabric / System performance
SYSTEMS			
Lighting	Low energy lighting (current regulations)	Low energy lighting (SAP doesn't allow for credit to be taken for LED lighting)	100% low energy lighting
Space Heating / DHW Heating Plant	Gas Boiler 88% (SEDBUK) + Interlock	Gas Boiler Efficiency, SEDBUK(2009) = 89.5%	CHP Efficiency: 61.8% CHP Heat Fraction: 0.8 CHP Electrical Efficiency: 30.05% Gas Boiler Heat Fraction: 0.2 Boiler Efficiency: 89%
Cooling	Air-cooled air conditioners EER:2.4 Water-cooled air conditioners EER:2.5	None	VRV - EER:3.2 (only on floor 8 of Building 1 and floor 6 of Building 2)
Ventilation	For continuous supply and extract with heat recovery should be not worst than 1.5 w/ls	Natural ventilation with intermittent extract fans	Vent Axia- Sentinel Kinetic Balanced with heat recovery SPF = 0.76 (1 additional wet room) SPF = 0.88 (2 additional wet rooms) SPF = 1.07 (3 additional wet rooms)

[7] Domestic Building Services Compliance Guide (HM Government, 2013 ed.)

Element	Minimum requirement, Part L1A 2013	SAP2012 Appendix R: Reference values	Proposed Fabric / System performance
Controls	Minimum controls package	Time and temperature zone control. Boiler interlock and weather compensation providing +3% boiler efficiency adjustment	Charging system linked to use of community heating, programmer, and TRVs
Other	Low water consumption in dwellings (typically less than 105l/person/day	Low water consumption in dwellings (typically less than 125l/person/day	Low water consumption in dwellings (typically less than 125l/person/day
Other	-	-	dark-coloured curtains or roller blinds Fraction curtains closed: 1 Windows are open half the time

Table 5: *SAP 2012 system parameters and values used for the Greenwood Place residential component*

6.6. Occupancy patterns and behaviour

In line with CIBSE and BS guidance, realistic algorithms for occupant behaviour, the use of windows and other adaptive behaviour were used in the dynamic thermal model, as well as a realistic occupancy schedule.

Internal heat gains are closely based on National Calculation Method (NCM) internal conditions (version 5.2.4). The following are the occupancy patterns applied in the model for living rooms and bedrooms:

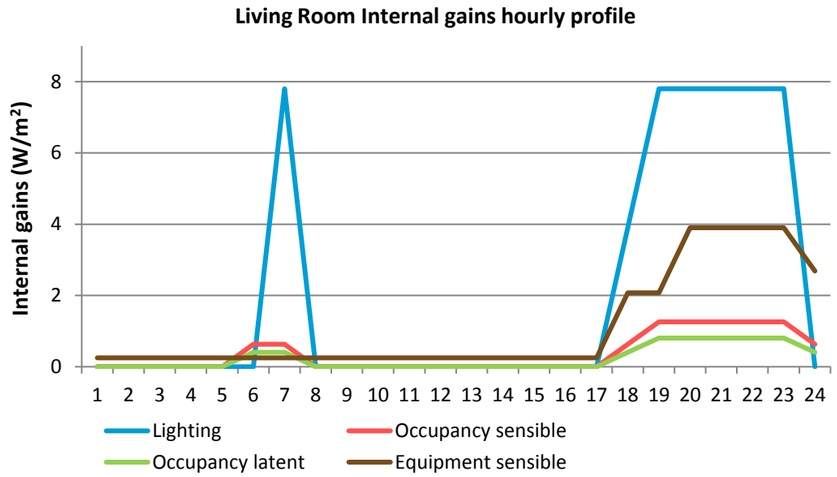

Figure 6: Hourly profile for Living rooms

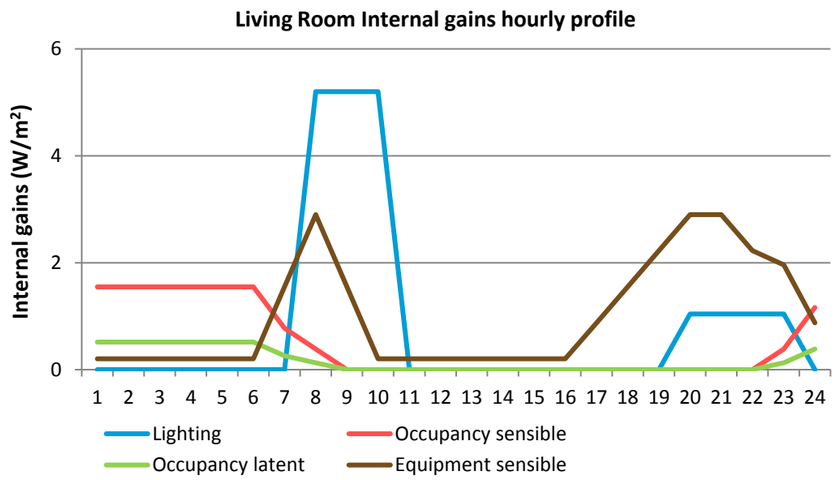

Figure 7: Hourly profile for Bedrooms

6.7. Windows/ vents operation

The natural ventilation scenario limits the windows' operation to dwelling occupied hours for a limited range of temperatures.

The model assumes that the windows partially open when the temperature in the space exceeds 22°C and they are fully open if the temperature exceeds 25°C.

The windows are assumed to have an openable area equivalent to 25% to 50% of the total window area (including frame). This has been calculated based on the drawings and elevations submitted by Squire and Partners on the 01/12/2015.

7. Results for Building 1

7.1. Natural ventilation, baseline case

7.1.1. Baseline overheating risk in bedrooms

Results for Building 1 - Level 6 bedrooms

			Assessment criteria	BR_P_Bldg1_F6_1	BR_P_Bldg1_F6_2	BR_P_Bldg1_F6_3	BR_P_Bldg1_F6_4	BR_P_Bldg1_F6_5	BR_P_Bldg1_F6_6	BR_P_Bldg1_F6_7	BR_P_Bldg1_F6_8 to 12
Level 6 bedrooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 7 bedrooms

			Assessment criteria	BR_P_Bldg1_F7_1	BR_P_Bldg1_F7_2	BR_P_Bldg1_F7_3	BR_P_Bldg1_F7_4	BR_P_Bldg1_F7_5	BR_P_Bldg1_F7_6	BR_P_Bldg1_F7_7	BR_P_Bldg1_F7_8 to 12
Level 7 bedrooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 8 bedrooms

			Assessment criteria	BR_P_Bldg1_F8_1	BR_P_Bldg1_F8_2	BR_P_Bldg1_F8_3	BR_P_Bldg1_F8_4	BR_P_Bldg1_F8_5	BR_P_Bldg1_F8_6	BR_P_Bldg1_F8_7	BR_P_Bldg1_F8_8 to 12
Level 8 bedrooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

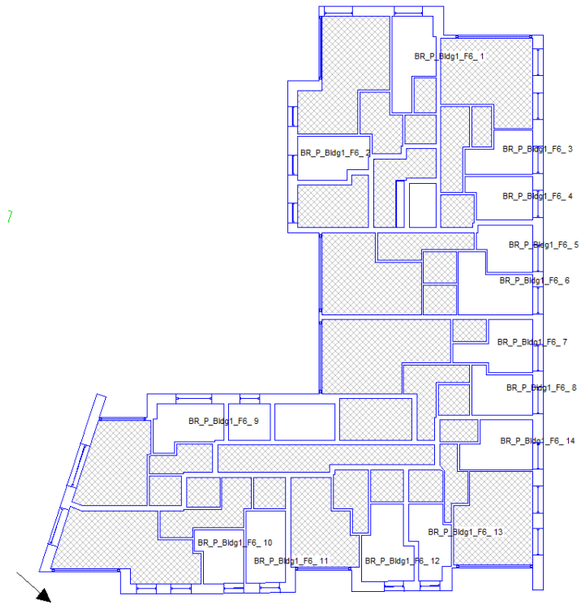

Figure 8: *Level 6 bedrooms in Building 1 (larger plan in Appendix A)*

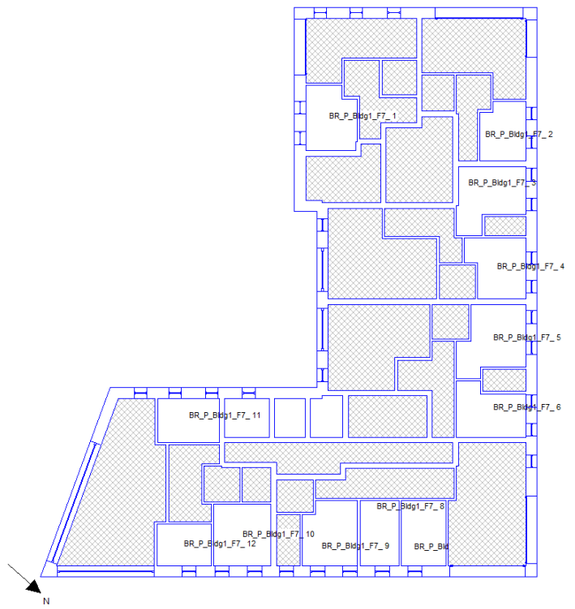

Figure 9: *Level 7 bedrooms in Building 1 (larger plan in Appendix A)*

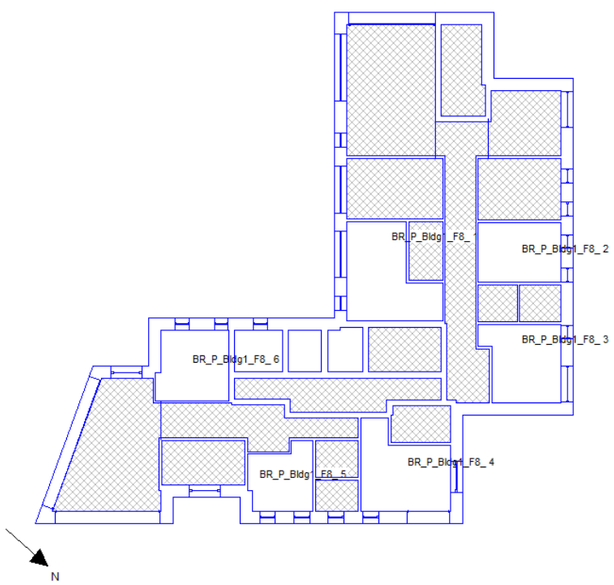

Figure 10: *Level 8 bedrooms in Building 1 (larger plan in Appendix A)*

Observations

The operative temperature in all bedrooms at Level 6, 7 and 8 of Building 1 pass all three TM52 criteria for BS Category II. Opening the windows during occupied hours enables all bedrooms to retain the temperature within acceptable tolerance.

7.1.1. Baseline overheating risk in living rooms

Results for Building 1 - Level 6 living rooms

		Assessment criteria		LR_P_Bldg1_F6_1	LR_P_Bldg1_F6_2	LR_P_Bldg1_F6_3	LR_P_Bldg1_F6_4	LR_P_Bldg1_F6_5	LR_P_Bldg1_F6_6	LR_P_Bldg1_F6_7	LR_P_Bldg1_F6_8
Level 6 living rooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0.508	0.871	0.073	0.073	0.508	0.799	0.145	0.799
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 7 living rooms

		Assessment criteria		LR_P_Bldg1_F7_1	LR_P_Bldg1_F7_2	LR_P_Bldg1_F7_3	LR_P_Bldg1_F7_4	LR_P_Bldg1_F7_5	LR_P_Bldg1_F7_6
Level 7 living rooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0.726	1.162	0.145	0.145	0.726	1.017
			Criterion 2	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 8 living rooms

		Assessment criteria		LR_P_Bldg1_F8_1	LR_P_Bldg1_F8_2
Level 8 living rooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0.871	0.871
			Criterion 2	0	1
			Criterion 3	0	1
	BS EN 15251 Category II			Pass	Fail

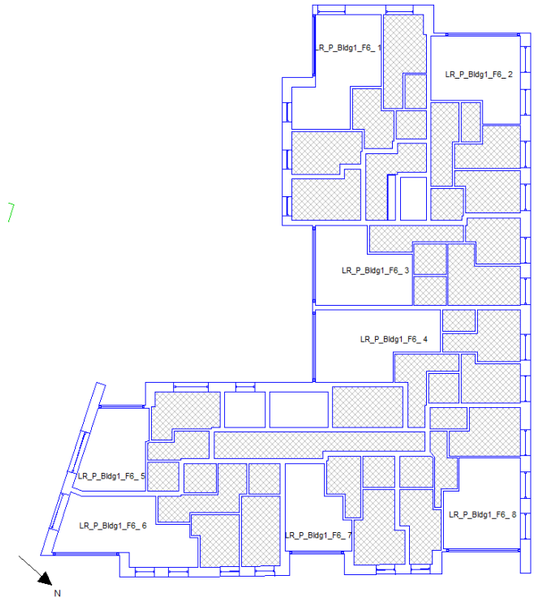

Figure 11: *Level 6 living rooms in Building 1 (larger plan in Appendix A)*

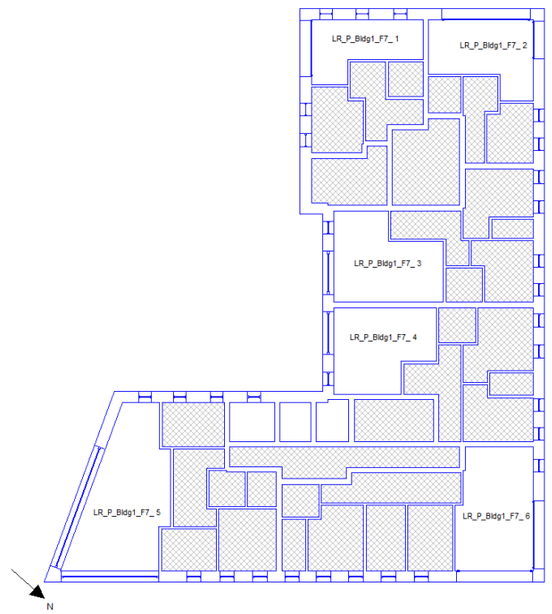

Figure 12: *Level 7 living rooms in Building 1 (larger plan in Appendix A)*

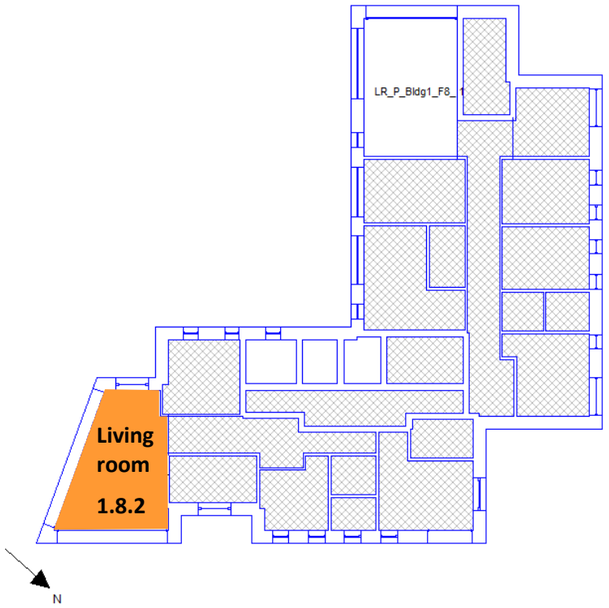

Figure 13: *Level 8 living rooms in Building 1 (larger plan in Appendix A)*

Observations

One living room (highlighted on Figure 13 above) on the top most exposed floor of Building 1 fails the TM 52 criteria. This living room is south-west facing and comfort cooling is proposed for this dwelling.

The operative temperature all other living rooms at Level 6, 7 and 8 of Building 1 pass all three TM52 criteria for BS Category II. Opening the windows during occupied hours enables these living rooms to retain the temperature within acceptable tolerance.

7.2. TM49 'Design Summer Years for London' Tests

The same zones were tested with three further design weather files, derived from TM49, namely:

- Test 1: 1976 - A year with a prolonged period of sustained warmth
- Test 2: 1989 - A moderately warm summer (current design year for London)
- Test 3: 2003 - A year with a very intense single warm spell

The results are detailed in Appendix B of this report.

The following observations are made:

1. All bedrooms with Test 1, 2 and 3 pass three or two out of three TM 52 criteria.
2. All living rooms with Test 2 (1989 TM49 design weather file) pass three or two out of three TM52 criteria.
3. Most living rooms with Test 1 and Test 3 fail the TM52 criteria.

It is important to note that TM49 design weather files represent extreme circumstances and it is very challenging to overcome overheating risk during the represented weather conditions through passive design measures and natural ventilation alone. A number of potential design and retrospective improvements are described in section 9 of this report.

8. Results for Building 2

8.1. Natural ventilation, baseline case

8.1.1. Baseline overheating risk in bedrooms

Results for Building 2 - Level 4 bedrooms

			Assessment criteria	BR_P_Bldg2_F4_1	BR_P_Bldg2_F4_2	BR_P_Bldg2_F4_3	BR_P_Bldg2_F4_4	BR_P_Bldg2_F4_5	BR_P_Bldg2_F4_6	BR_P_Bldg2_F4_7	BR_P_Bldg2_F4_8 to 9
Level 4 bedrooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

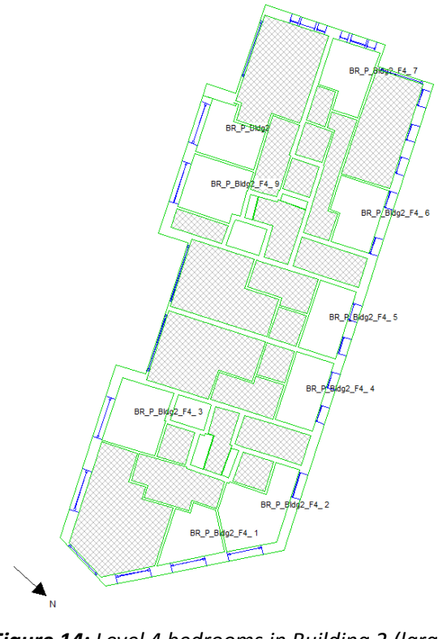

Figure 14: *Level 4 bedrooms in Building 2 (larger plan in Appendix A)*

Results for Building 2 - Level 5 bedrooms

			Assessment criteria	BR_P_Bldg2_F5_1	BR_P_Bldg2_F5_2	BR_P_Bldg2_F5_3	BR_P_Bldg2_F5_4	BR_P_Bldg2_F5_5	BR_P_Bldg2_F5_6	BR_P_Bldg2_F5_7	BR_P_Bldg2_F5_8 to 9
Level 5 bedrooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

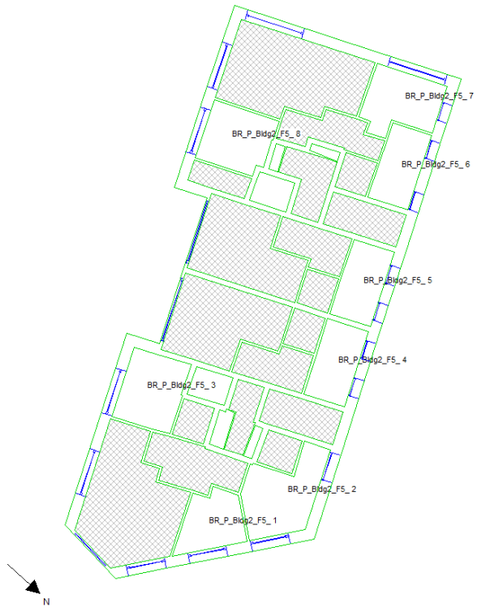

Figure 15: *Level 5 bedrooms in Building 2 (larger plan in Appendix A)*

Results for Building 2 - Level 6 bedrooms

			Assessment criteria	LR_P_Bldg2_F6_1	LR_P_Bldg1_F6_2	LR_P_Bldg1_F6_3
Level 6 bedrooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0
			Criterion 2	0	0	0
			Criterion 3	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass

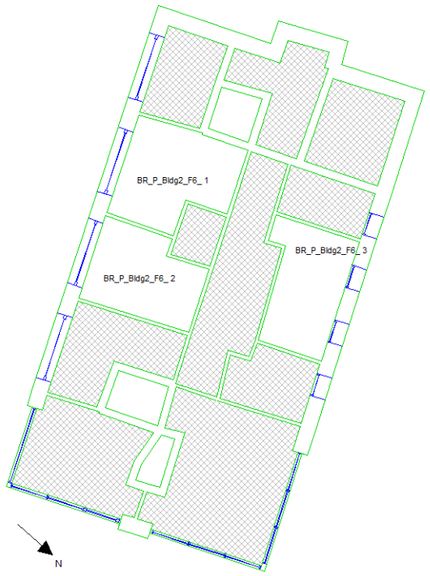

Figure 16: *Level 6 bedrooms in Building 2 (larger plan in Appendix A)*

Observations

The operative temperature in all bedrooms at Level 4, 5 and 6 of Building 2 pass all three TM52 criteria for BS Category II. Opening the windows during occupied hours enables all bedrooms to retain the temperature within acceptable tolerance.

8.1.2. Baseline overheating risk in living rooms

Results for Building 2 - Level 4 living rooms

		Assessment criteria		LR_P_Bldg2_F4_1	LR_P_Bldg2_F4_2	LR_P_Bldg2_F4_3	LR_P_Bldg2_F4_5	LR_P_Bldg2_F4_4
Level 4 Living rooms	TM52 and BS EN 15251	*Category II*	Criterion 1	Not modelled as floors above Level 4 pass.				0.363
			Criterion 2					0
			Criterion 3					0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass

Results for Building 2 - Level 5 living rooms

		Assessment criteria		LR_P_Bldg2_F5_1	LR_P_Bldg2_F5_2	LR_P_Bldg2_F5_3	LR_P_Bldg2_F5_4
Level 5 Living rooms	TM52 and BS EN 15251	*Category II*	Criterion 1	0.363	0.073	0.145	1.888
			Criterion 2	0	0	0	2
			Criterion 3	0	0	0	2
	BS EN 15251 Category II			Pass	Pass	Pass	Fail

Results for Building 2 - Level 6 living rooms

		Assessment criteria		LR_P_Bldg2_F6_1
Level 6 Living rooms	TM52 and BS EN 15251	*Category II*	Criterion 1	1.161
			Criterion 2	0
			Criterion 3	1
	BS EN 15251 Category II			Pass

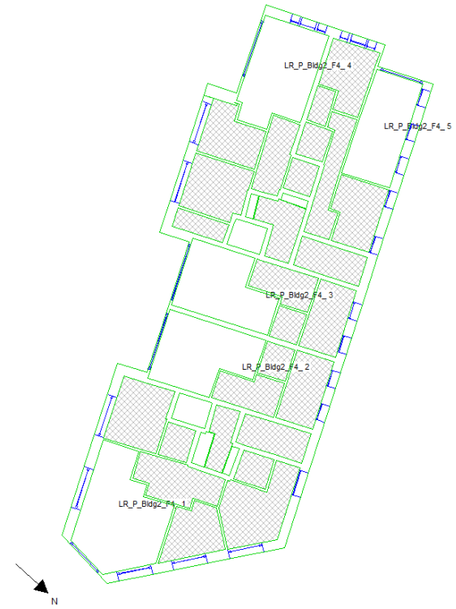

Figure 17: *Level 4 living rooms in Building 2 (larger plan in Appendix A)*

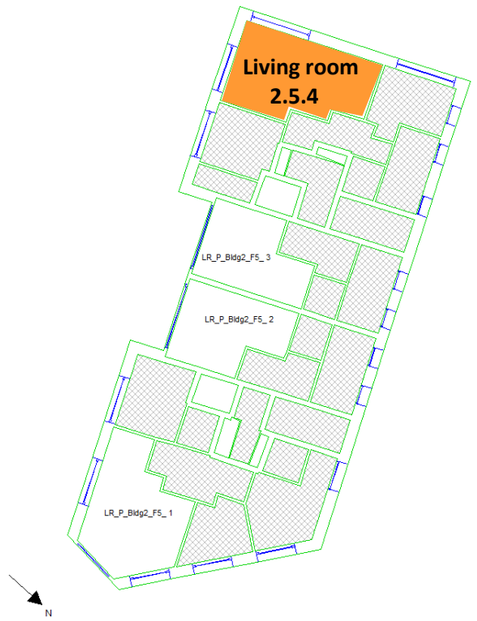

Figure 18: *Level 5 living rooms in Building 2 (larger plan in Appendix A)*

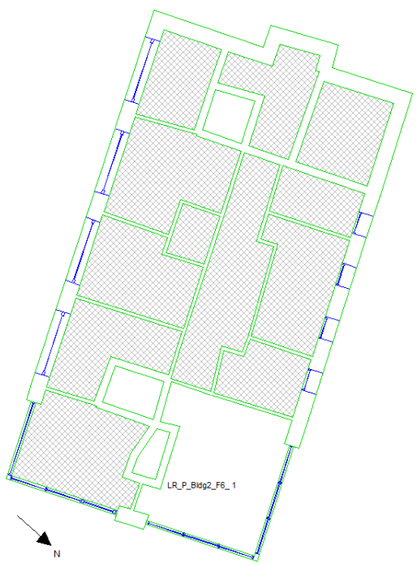

Figure 19: *Level 6 living rooms in Building 2 (larger plan in Appendix A)*

Observations

One living room (highlighted on Figure 18 above) on the most exposed corner in floor 5 of Building 2 fails the TM 52 criteria for a maximum of 2 days per year. This living room is south-west facing and the following is recommended in order to reduce the risk of overheating:

- Installation of external blinds or external shading to terrace openings;
- Increasing the proportion of openable glazed areas to provide a higher level of natural ventilation;
- Considering use of ceiling fans to increase air movement in the dwelling; and
- Considering a high level of thermal mass surfaces in living rooms to reduce peak temperatures.

The operative temperature all other living rooms at Level 4, 5 and 6 of Building 2 pass all three TM52 criteria for BS Category II. Opening the windows during occupied hours enables these living rooms to retain the temperature within acceptable tolerance.

8.2. TM49 'Design Summer Years for London' Tests

The same zones were tested with three further design weather files, derived from TM49, namely:

- Test 1: 1976 - A year with a prolonged period of sustained warmth
- Test 2: 1989 - A moderately warm summer (current design year for London)
- Test 3: 2003 - A year with a very intense single warm spell

The results are detailed in Appendix C of this report.

The following observations are made:

4. All bedrooms with Test 1, 2 and 3 pass three or two out of three TM 52 criteria.
5. All living rooms with Test 2 (1989 TM49 design weather file) pass three or two out of three TM52 criteria.
6. Most living rooms with Test 1 and Test 3 fail the TM52 criteria.

It is important to note that TM49 design weather files represent extreme circumstances and it is very challenging to overcome overheating risk during the represented weather conditions through passive design measures and natural ventilation alone. A number of potential design and retrospective improvements are described in section 9 of this report.

8.1. Air-conditioned dwelling thermal comfort

8.1.1. Summer thermal comfort

The living room in the flat 1.8.2 fails the TM52 criteria. Active cooling with a set point at 22°C is proposed for this dwelling. A PPD/PMV analysis has therefore been carried out to ensure the thermal comfort in this particular living room complies with the CIBSE Guide A guidance (PPD / PMV).

The results of the analysis for the living room 1.8.2 are listed in the table below.

SUMMER				
	P.O.T. (°C)	**Fr (%)**	**PMV**	**PPD (%)**
LR_P_Bldg1_F8_ 2	24.9	0.0%	0.0	5.0%
Fr = Frequency of temp. above 26.0°C during occupied hours		*PMV = Predicted Mean Vote*		
P.O.T. = Peak Operative Temperature		*PPD = Predicted Percentage Dissatisfied*		

Table 6: *Summer Thermal Comfort results for an air-conditioned living room*

The PMV does not exceed 0.5 (equivalent to a PPD of 10%) for more than 3% of annual occupied hours. The living 1.8.2 complies with the CIBSE Guide A recommendations for summer thermal comfort.

9. Conclusions and recommendations

The overheating risk analysis of the residential element of the Greenwood development concludes that

1. When windows are opened during occupied hours, all bedrooms and most living rooms overcome the risk of overheating criteria when tested in accordance with CIBSE Guide A (2006), TM52 and BS EN 15251:2007 methodologies.
2. The only living spaces that fail the BS EN 15251:2007 and CIBSE TM52 test are the SW facing rooms at level 5 of Building 2 and the SW facing room at level 8 of Building 2 only. This implies that the natural ventilation alone is not sufficient to overcome the risk of overheating during hotter months and for this reason it is recommended that additional measures are implemented in these specific locations (see recommendations below).
3. When tested against CIBSE TM 49 weather files, all bedrooms fair well against BS EN 15251:2007 and TM 52 criteria. Living rooms pass all criteria in a 1989 weather scenario (moderately warm summer) but result in temperatures beyond acceptable limits during a prolonged period of sustained warmth and a very intense single warm spell.
4. It is important to note that TM49 design weather files represent extreme circumstances and it is very challenging to overcome overheating risk during the represented weather conditions through passive design measures and natural ventilation alone.

In conclusion, the natural ventilation strategy and a windows glass g-value limited to 0.4 contribute to eliminating the risk of overheating in most apartments.

Where the TM52 criteria are not met, additional measures are recommended to help limit the overheating risk, these include:

- Installation of external blinds or external shading to terrace openings;
- Increasing the proportion of openable glazed areas to provide a higher level of natural ventilation;
- Considering use of ceiling fans to increase air movement in the dwelling; and
- Considering a high level of thermal mass surfaces in living rooms to reduce peak temperatures.

According to BS EN 15251 (2007) it is possible to increase the comfort temperature upper limit if the operative temperature (t_o) is higher than 25°C and internal air speed is higher than 0.1 m/s, using personal fans although this effect has not been tested here.

An air-conditioning system is also proposed to mitigate the risk of overheating in the top floor dwellings of Building 1 and Building 2.

This overheating risk assessment was undertaken for a category II expectation level, as recommend by BS EN 15251:2007. Spaces that are to be occupied by very sensitive and fragile persons should be tested against category I tolerance criteria.

APPENDIX A – Tested floors in the Dynamic Thermal Model

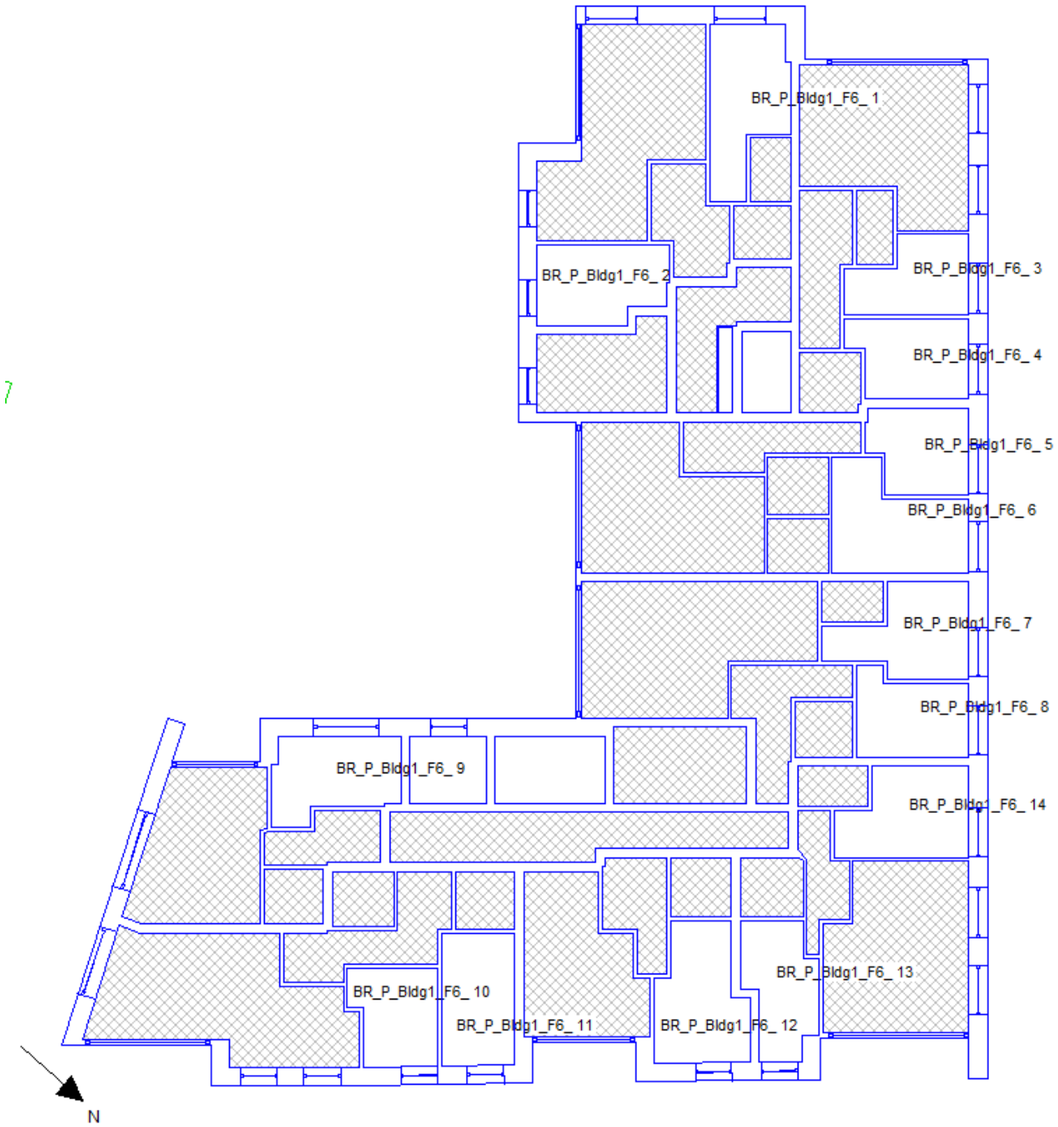

Figure 20: *Floor 6 bedrooms in Building 1 in overheating risk dynamic thermal model*

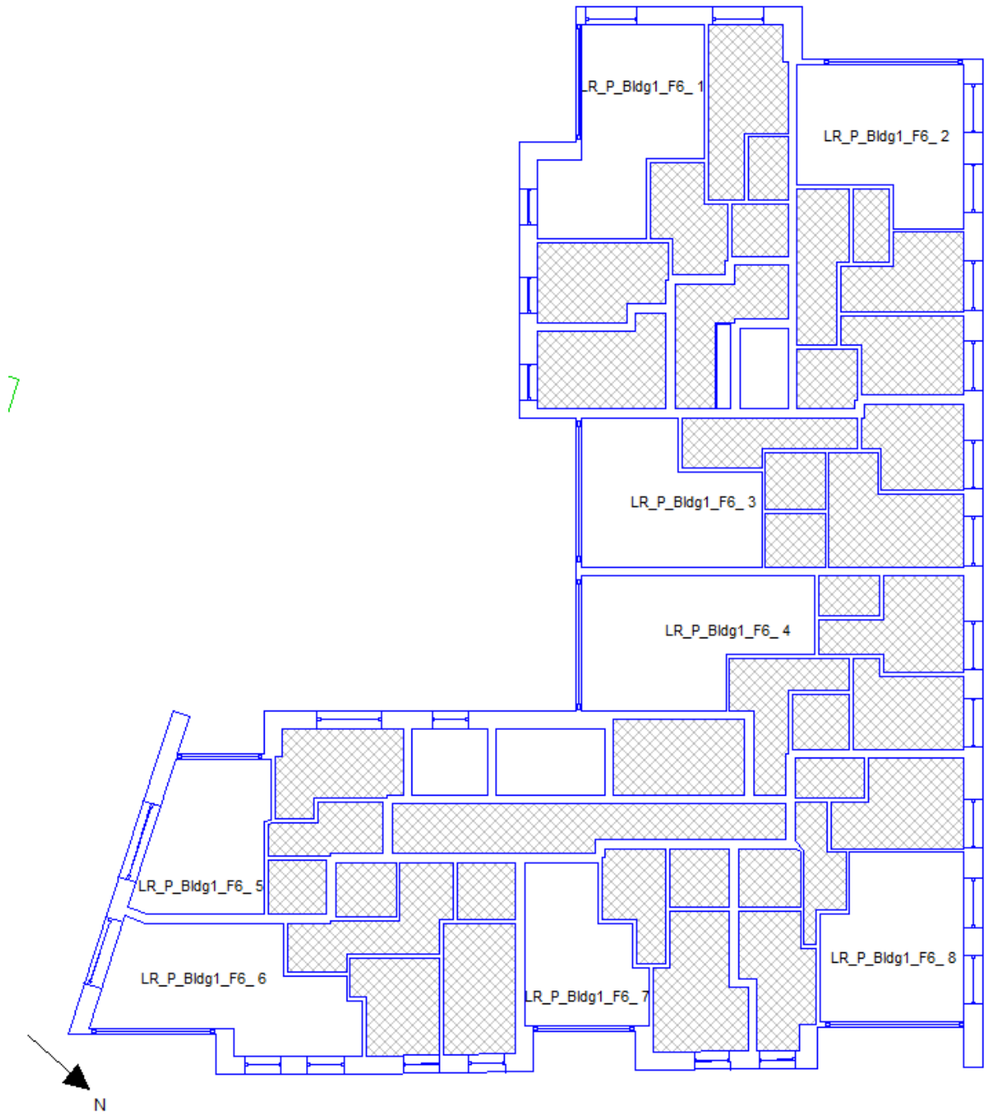

Figure 21: *Floor 6 living rooms in Building 1 in overheating risk dynamic thermal model*

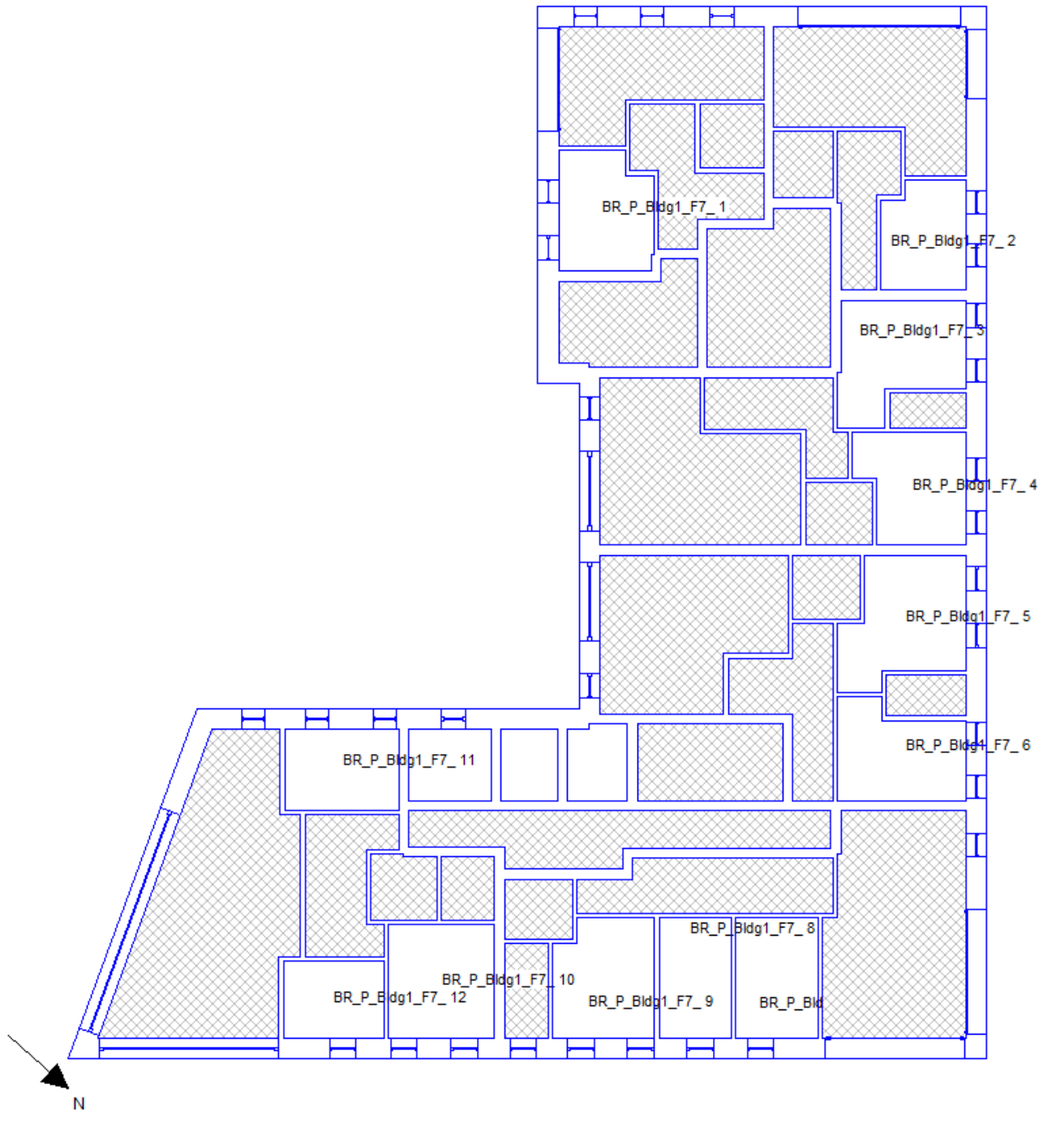

Figure 22: *Floor 7 bedrooms in Building 1 in overheating risk dynamic thermal model*

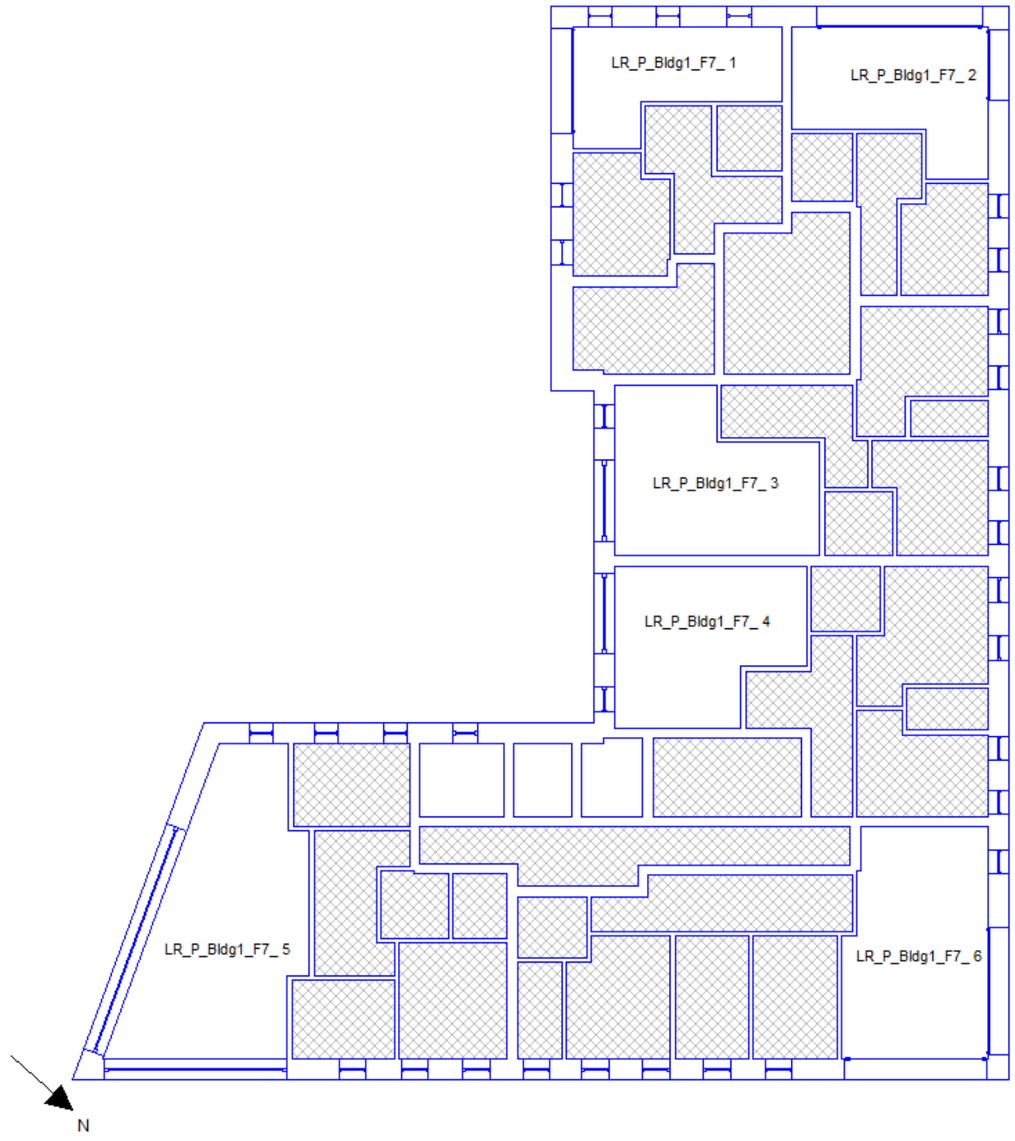

Figure 23: *Floor 7 living rooms in Building 1 in overheating risk dynamic thermal model*

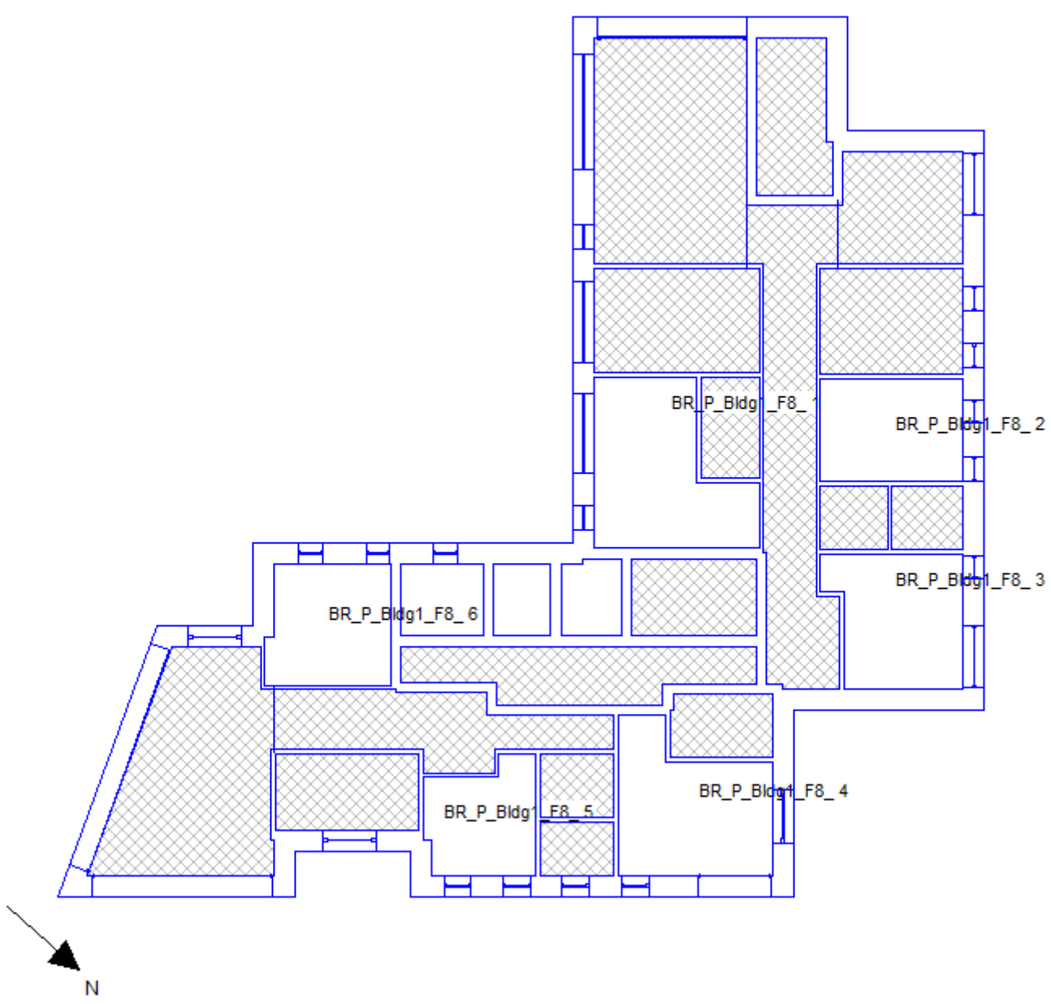

Figure 24: *Floor 8 bedrooms in Building 1 in overheating risk dynamic thermal model*

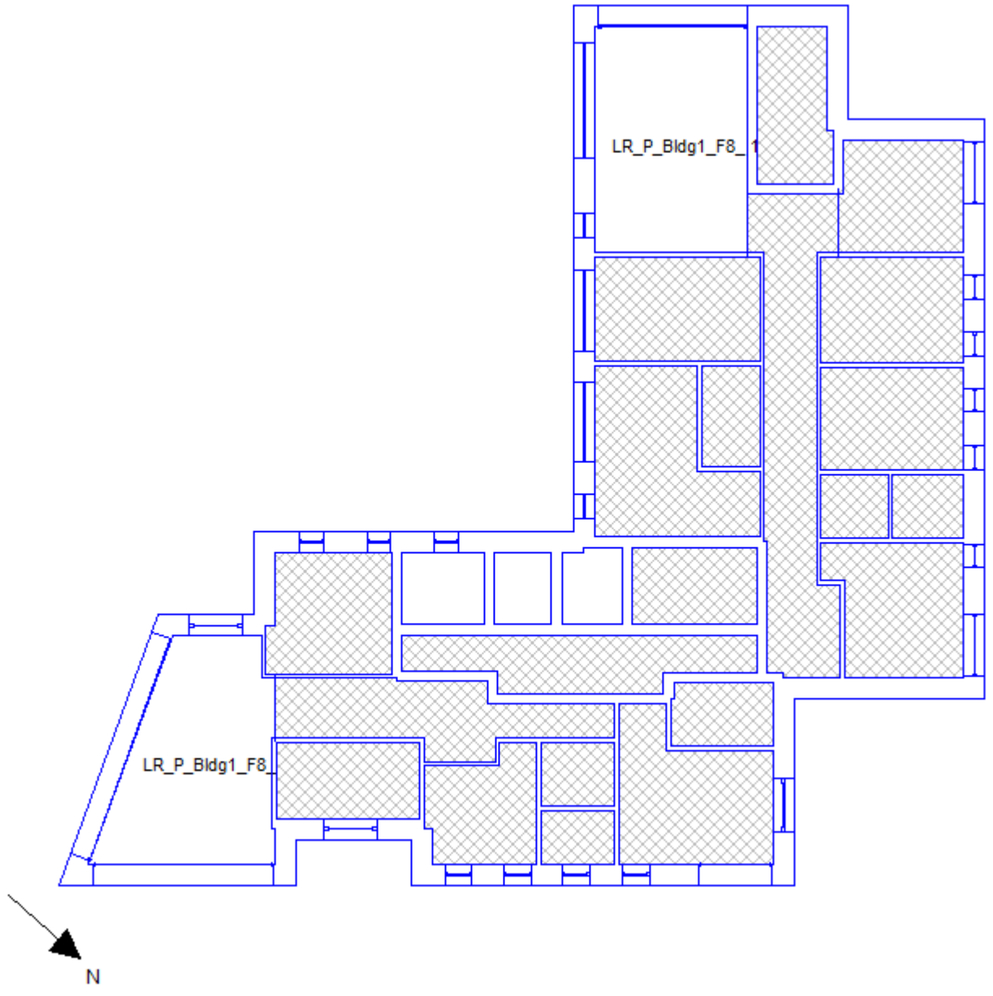

Figure 25: *Floor 8 living rooms in Building 1 in overheating risk dynamic thermal model*

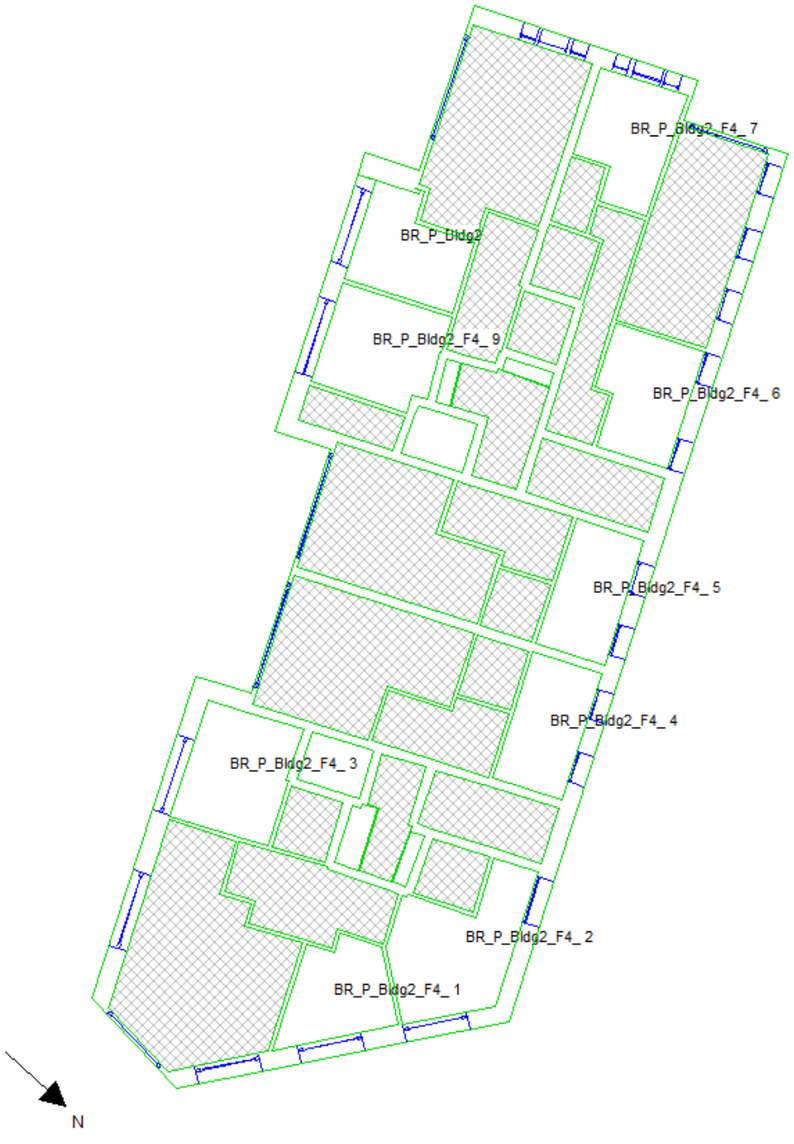

Figure 26: *Floor 4 bedrooms in Building 2 in overheating risk dynamic thermal model*

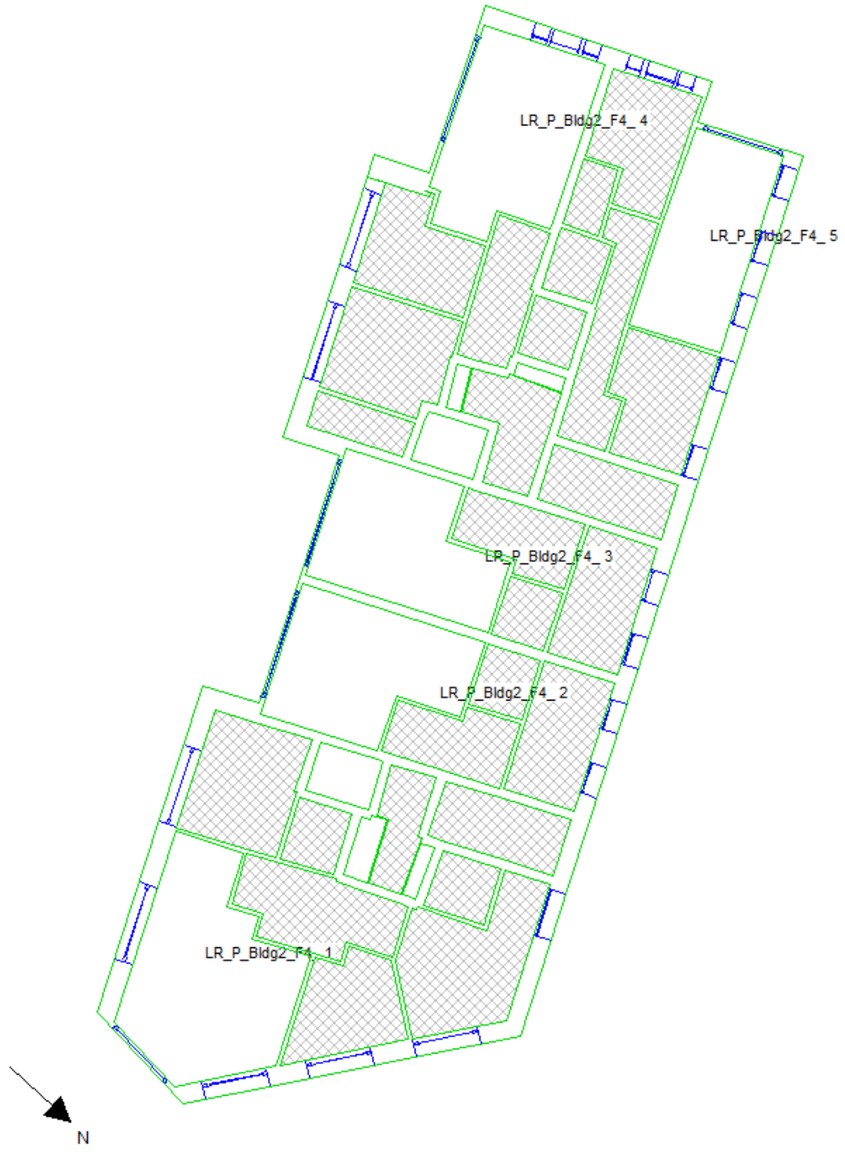

Figure 27: *Floor 4 living rooms in Building 2 in overheating risk dynamic thermal model*

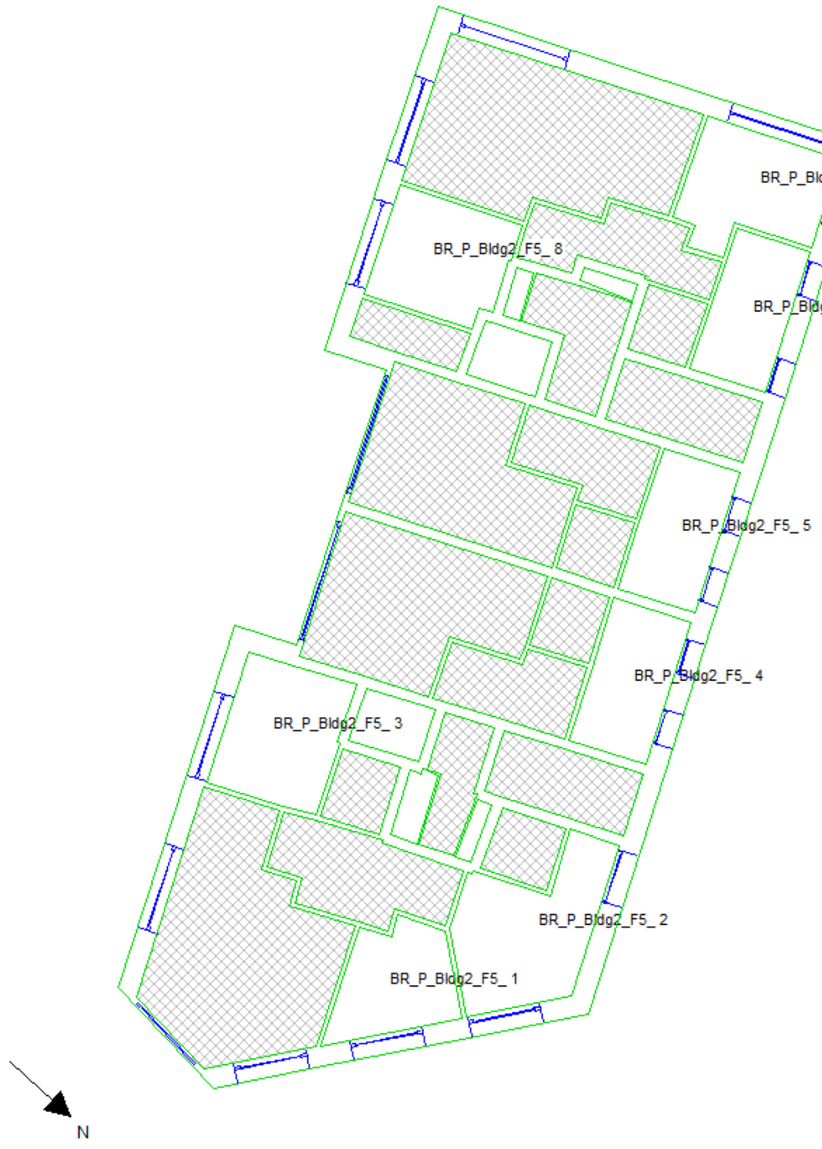

Figure 28: *Floor 5 bedrooms in Building 2 in overheating risk dynamic thermal model*

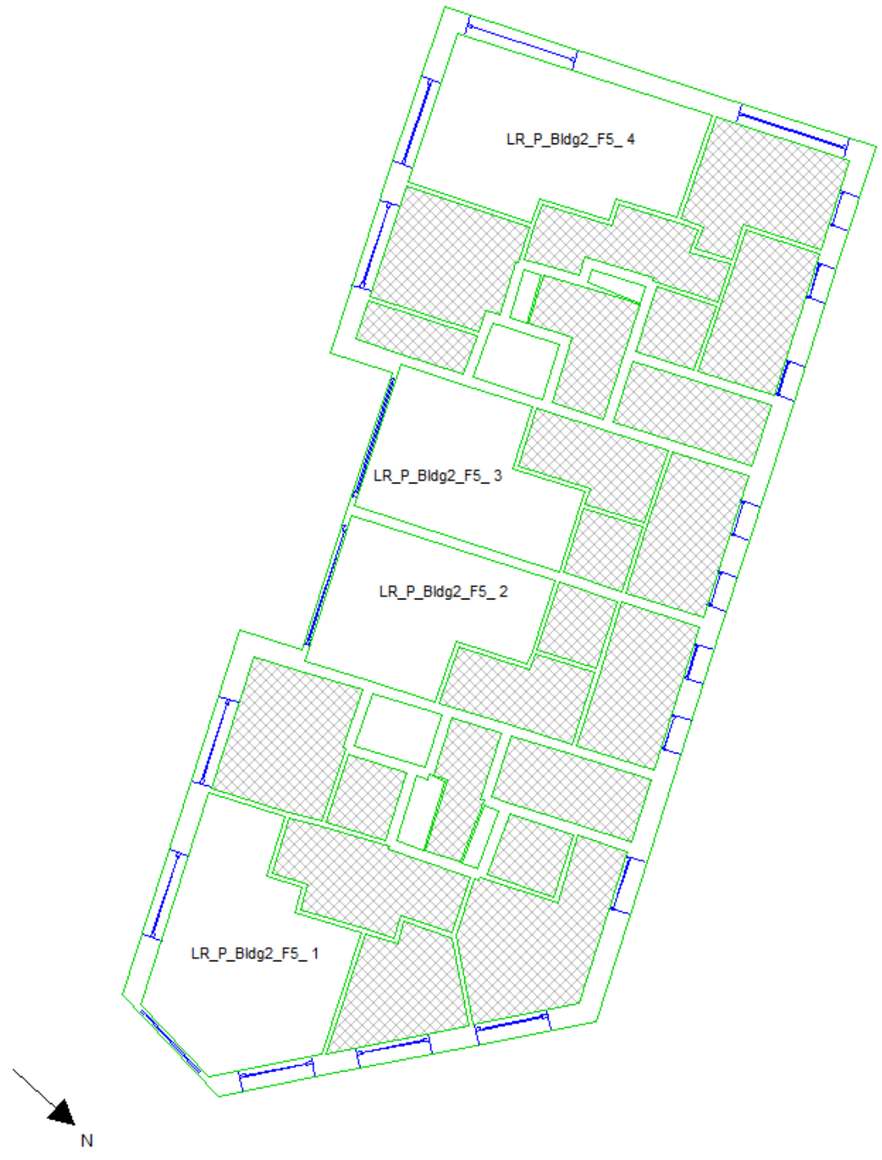

Figure 29: *Floor 5 living rooms in Building 2 in overheating risk dynamic thermal model*

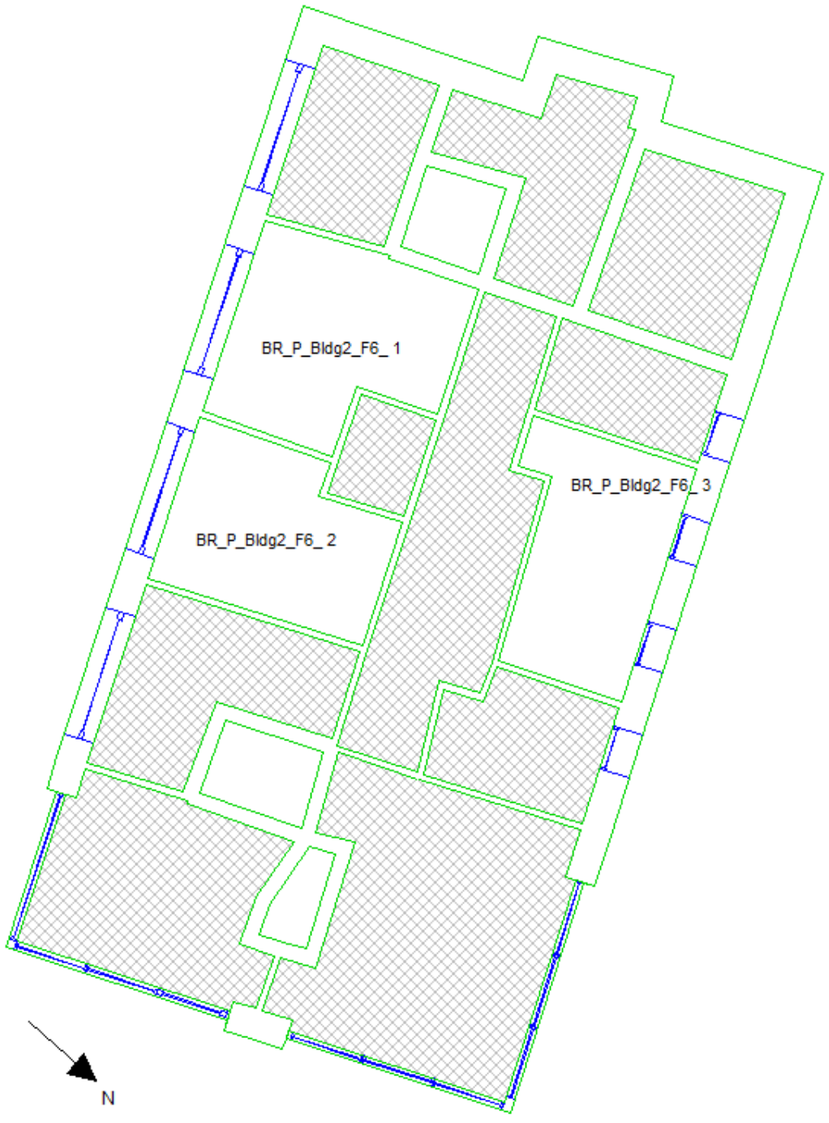

Figure 30: *Floor 6 bedrooms in Building 2 in overheating risk dynamic thermal model*

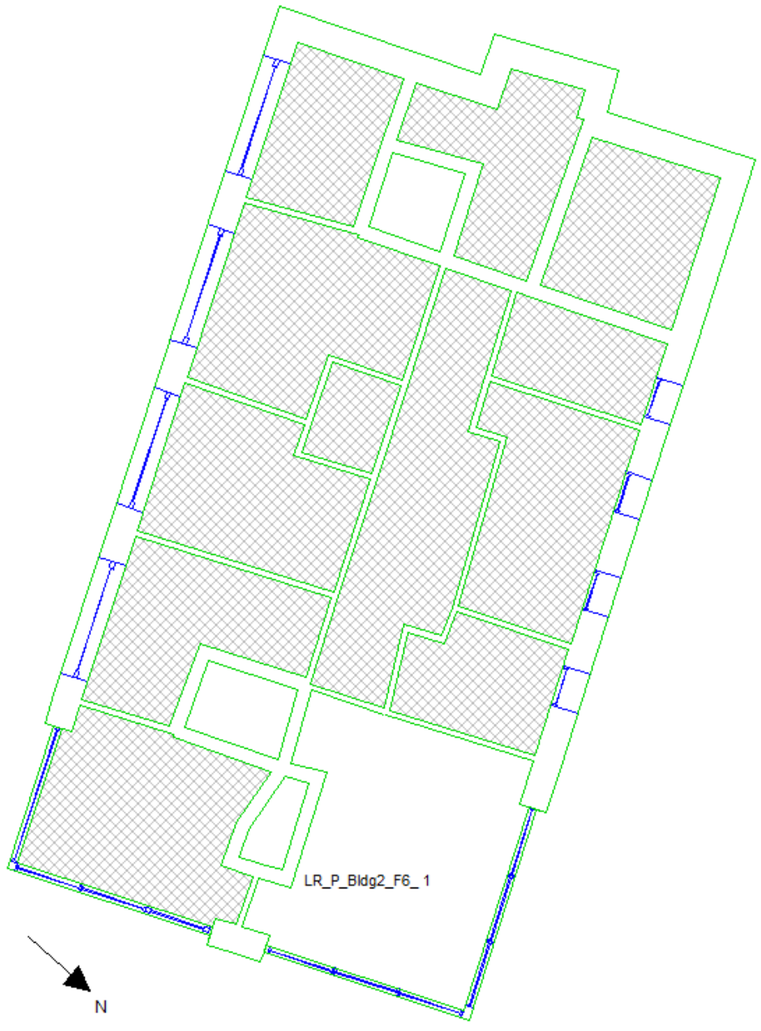

Figure 31: *Floor 6 living rooms in Building 2 in overheating risk dynamic thermal model*

APPENDIX B – TM49 Detailed Results for Building 1

Building 1 - Test 1 (1976 TM49 design weather file) overheating risk in bedrooms

Results for Building 1 - Level 6 bedrooms

Level 6 Bedrooms			Assessment criteria	BR_P_Bldg1_F6_1	BR_P_Bldg1_F6_2	BR_P_Bldg1_F6_3	BR_P_Bldg1_F6_4	BR_P_Bldg1_F6_5	BR_P_Bldg1_F6_6	BR_P_Bldg1_F6_7	BR_P_Bldg1_F6_8 to 12
TM52 and BS EN 15251	*Category II*		Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II				Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 7 bedrooms

Level 7 Bedroom			Assessment criteria	BR_P_Bldg1_F7_1	BR_P_Bldg1_F7_2	BR_P_Bldg1_F7_3	BR_P_Bldg1_F7_4	BR_P_Bldg1_F7_5	BR_P_Bldg1_F7_6	BR_P_Bldg1_F7_7	BR_P_Bldg1_F7_8 to 12
TM52 and BS EN 15251	*Category II*		Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II				Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 8 bedrooms

S Level 8 Bedrooms			Assessment criteria	BR_P_Bldg1_F8_1	BR_P_Bldg1_F8_2	BR_P_Bldg1_F8_3	BR_P_Bldg1_F8_4	BR_P_Bldg1_F8_5	BR_P_Bldg1_F8_6	BR_P_Bldg1_F8_7	BR_P_Bldg1_F8_8 to 12
TM52 and BS EN 15251	*Category II*		Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II				Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Building 1 - Test 1 (1976 TM49 design weather file) overheating risk in living rooms

Results for Building 1 - Level 6 living rooms

Level 6 living rooms			Assessment criteria	LR_P_Bldg1_F6_1	LR_P_Bldg1_F6_2	LR_P_Bldg1_F6_3	LR_P_Bldg1_F6_4	LR_P_Bldg1_F6_5	LR_P_Bldg1_F6_6	LR_P_Bldg1_F6_7	LR_P_Bldg1_F6_8
TM52 and BS EN 15251	*Category II*		Criterion 1	1.60	1.82	0.94	0.87	1.74	2.69	1.09	1.82
			Criterion 2	2	3	1	1	2	4	1	3
			Criterion 3	1	2	0	0	1	2	0	2
BS EN 15251 Category II				Fail	Fail	Pass	Pass	Fail	Fail	Pass	Fail

Results for Building 1 - Level 7 living rooms

Level 7 living rooms			Assessment criteria	LR_P_Bldg1_F7_1	LR_P_Bldg1_F7_2	LR_P_Bldg1_F7_3	LR_P_Bldg1_F7_4	LR_P_Bldg1_F7_5	LR_P_Bldg1_F7_6
TM52 and BS EN 15251	*Category II*		Criterion 1	2.18	2.40	1.31	1.09	2.18	2.11
			Criterion 2	3	3	1	1	3	4
			Criterion 3	2	3	0	0	4	3
BS EN 15251 Category II				Fail	Fail	Pass	Pass	Fail	Fail

Results for Building 1 - Level 8 living rooms

Level 8 living rooms			Assessment criteria	LR_P_Bldg 1_F8_1	LR_P_Bldg 1_F8_2
TM52 and BS EN 15251	*Category II*		Criterion 1	2.25	2.40
			Criterion 2	3	3
			Criterion 3	3	4
BS EN 15251 Category II				Fail	Fail

Building 1 - Test 2 (1989 TM49 design weather file) overheating risk in bedrooms

Results for Building 1 - Level 6 bedrooms

Level 6 Bedrooms		Assessment criteria	BR_P_Bldg1_F6_1	BR_P_Bldg1_F6_2	BR_P_Bldg1_F6_3	BR_P_Bldg1_F6_4	BR_P_Bldg1_F6_5	BR_P_Bldg1_F6_6	BR_P_Bldg1_F6_7	BR_P_Bldg1_F6_8 to 12
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 7 bedrooms

Level 7 Bedrooms		Assessment criteria	BR_P_Bldg1_F7_1	BR_P_Bldg1_F7_2	BR_P_Bldg1_F7_3	BR_P_Bldg1_F7_4	BR_P_Bldg1_F7_5	BR_P_Bldg1_F7_6	BR_P_Bldg1_F7_7	BR_P_Bldg1_F7_8 to 12
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 8 bedrooms

Level 8 Bedrooms		Assessment criteria	BR_P_Bldg1_F8_1	BR_P_Bldg1_F8_2	BR_P_Bldg1_F8_3	BR_P_Bldg1_F8_4	BR_P_Bldg1_F8_5	BR_P_Bldg1_F8_6	BR_P_Bldg1_F8_7	BR_P_Bldg1_F8_8 to 12
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Building 1 - Test 2 (1989 TM49 design weather file) overheating risk in living rooms

Results for Building 1 - Level 6 living rooms

Level 6 living rooms		Assessment criteria	LR_P_Bldg1_F6_1	LR_P_Bldg1_F6_2	LR_P_Bldg1_F6_3	LR_P_Bldg1_F6_4	LR_P_Bldg1_F6_5	LR_P_Bldg1_F6_6	LR_P_Bldg1_F6_7	LR_P_Bldg1_F6_8
TM52 and BS EN 15251	*Category II*	Criterion 1	0.58	0.65	0	0	0.59	0.87	0.22	0.51
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 7 living rooms

Level 7 living rooms		Assessment criteria	LR_P_Bldg1_F7_1	LR_P_Bldg1_F7_2	LR_P_Bldg1_F7_3	LR_P_Bldg1_F7_4	LR_P_Bldg1_F7_5	LR_P_Bldg1_F7_6	
TM52 and BS EN 15251	*Category II*	Criterion 1	0.65	0.87	0.29	0.22	0.87	0.58	
		Criterion 2	0	0	0	0	2	0	
		Criterion 3	0	0	0	0	0	0	
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 8 living rooms

Level 8 living rooms		Assessment criteria	LR_P_Bldg 1_F8_1	LR_P_Bldg 1_F8_2
TM52 and BS EN 15251	*Category II*	Criterion 1	0.80	0.87
		Criterion 2	0	2
		Criterion 3	0	0
BS EN 15251 Category II			Pass	Pass

Building 1 - Test 3 (2003 TM49 design weather file) overheating risk in bedrooms

Results for Building 1 - Level 6 bedrooms

Level 6 Bedrooms		Assessment criteria	BR_P_Bldg1_F6_1	BR_P_Bldg1_F6_2	BR_P_Bldg1_F6_3	BR_P_Bldg1_F6_4	BR_P_Bldg1_F6_5	BR_P_Bldg1_F6_6	BR_P_Bldg1_F6_7	BR_P_Bldg1_F6_8 to 12
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 7 bedrooms

Level 7 Bedrooms		Assessment criteria	BR_P_Bldg1_F7_1	BR_P_Bldg1_F7_2	BR_P_Bldg1_F7_3	BR_P_Bldg1_F7_4	BR_P_Bldg1_F7_5	BR_P_Bldg1_F7_6	BR_P_Bldg1_F7_7	BR_P_Bldg1_F7_8 to 12
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 1 - Level 8 bedrooms

Level 8 Bedrooms		Assessment criteria	BR_P_Bldg1_F8_1	BR_P_Bldg1_F8_2	BR_P_Bldg1_F8_3	BR_P_Bldg1_F8_4	BR_P_Bldg1_F8_5	BR_P_Bldg1_F8_6	BR_P_Bldg1_F8_7	BR_P_Bldg1_F8_8 to 12
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Building 1 - Test 3 (2003 TM49 design weather file) overheating risk in living rooms

Results for Building 1 - Level 6 living rooms

Level 6 living rooms		Assessment criteria	LR_P_Bldg1_F6_1	LR_P_Bldg1_F6_2	LR_P_Bldg1_F6_3	LR_P_Bldg1_F6_4	LR_P_Bldg1_F6_5	LR_P_Bldg1_F6_6	LR_P_Bldg1_F6_7	LR_P_Bldg1_F6_8
TM52 and BS EN 15251	*Category II*	Criterion 1	1.74	1.53	1.02	1.02	2.03	2.69	1.02	1.53
		Criterion 2	4	4	3	2	4	4	3	4
		Criterion 3	5	6	0	0	7	7	0	5
BS EN 15251 Category II			Fail	Fail	Pass	Pass	Fail	Fail	Pass	Fail

Results for Building 1 - Level 7 living rooms

Level 7 living rooms		Assessment criteria	LR_P_Bldg1_F7_1	LR_P_Bldg1_F7_2	LR_P_Bldg1_F7_3	LR_P_Bldg1_F7_4	LR_P_Bldg1_F7_5	LR_P_Bldg1_F7_6
TM52 and BS EN 15251	*Category II*	Criterion 1	2.251271	2.323893	1.161946	1.089325	2.687001	1.888163
		Criterion 2	4	4	3	3	4	4
		Criterion 3	9	7	0	0	9	6
BS EN 15251 Category II			Fail	Fail	Pass	Pass	Fail	Fail

Results for Building 1 - Level 8 living rooms

Level 8 living rooms		Assessment criteria	LR_P_Bldg 1_F8_1	LR_P_Bldg 1_F8_2
TM52 and BS EN 15251	*Category II*	Criterion 1	2.40	2.76
		Criterion 2	4	4
		Criterion 3	7	9
BS EN 15251 Category II			Fail	Fail

APPENDIX C – TM49 Detailed Results for Building 2

Building 2 - Test 1 (1976 TM49 design weather file) overheating risk in bedrooms

Results for Building 2 - Level 4 bedrooms

Level 4 Bedrooms		Assessment criteria	BR_P_Bldg2_F4_1	BR_P_Bldg2_F4_2	BR_P_Bldg2_F4_3	BR_P_Bldg2_F4_4	BR_P_Bldg2_F4_5	BR_P_Bldg2_F4_6	BR_P_Bldg2_F4_7	BR_P_Bldg2_F4_8 to 9
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 2 - Level 5 bedrooms

Level 5 Bedrooms		Assessment criteria	BR_P_Bldg2_F5_1	BR_P_Bldg2_F5_2	BR_P_Bldg2_F5_3	BR_P_Bldg2_F5_4	BR_P_Bldg2_F5_5	BR_P_Bldg2_F5_6	BR_P_Bldg2_F5_7	BR_P_Bldg2_F5_8 to 9
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 2 - Level 6 bedrooms

Level 6 Bedrooms		Assessment criteria	LR_P_Bldg 2_F6_1	LR_P_Bldg 1_F6_2	LR_P_Bldg 1_F6_3
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0
		Criterion 2	0	0	0
		Criterion 3	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass

Building 2 - Test 1 (1976 TM49 design weather file) overheating risk in living rooms

Results for Building 2 - Level 4 living rooms

Level 4 living rooms		Assessment criteria	LR_P_Bldg2_F4_4
TM52 and BS EN 15251	*Category II*	Criterion 1	1.23
		Criterion 2	3
		Criterion 3	4
BS EN 15251 Category II			Fail

Results for Building 2 - Level 5 living rooms

Level 5 living rooms		Assessment criteria	LR_P_Bldg2_F5_1	LR_P_Bldg2_F5_2	LR_P_Bldg2_F5_3	LR_P_Bldg2_F5_4
TM52 and BS EN 15251	*Category II*	Criterion 1	1.60	0.94	1.16	3.05
		Criterion 2	2	1	1	3
		Criterion 3	1	0	0	4
BS EN 15251 Category II			Fail	Pass	Pass	Fail

Results for Building 2 - Level 6 living rooms

Level 6 living rooms		Assessment criteria	LR_P_Bldg 2_F6_1
TM52 and BS EN 15251	*Category II*	Criterion 1	2.32
		Criterion 2	3
		Criterion 3	4
BS EN 15251 Category II			Fail

Building 2 - Test 2 (1989 TM49 design weather file) overheating risk in bedrooms

Results for Building 2 - Level 4 bedrooms

Level 4 Bedrooms		Assessment criteria		BR_P_Bldg2_F4_1	BR_P_Bldg2_F4_2	BR_P_Bldg2_F4_3	BR_P_Bldg2_F4_4	BR_P_Bldg2_F4_5	BR_P_Bldg2_F4_6	BR_P_Bldg2_F4_7	BR_P_Bldg2_F4_8 to 9
	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 2 - Level 5 bedrooms

Level 5 Bedrooms		Assessment criteria		BR_P_Bldg2_F5_1	BR_P_Bldg2_F5_2	BR_P_Bldg2_F5_3	BR_P_Bldg2_F5_4	BR_P_Bldg2_F5_5	BR_P_Bldg2_F5_6	BR_P_Bldg2_F5_7	BR_P_Bldg2_F5_8 to 9
	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
			Criterion 2	0	0	0	0	0	0	0	0
			Criterion 3	0	0	0	0	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 2 - Level 6 bedrooms

Level 6 Bedrooms		Assessment criteria		LR_P_Bldg2_F6_1	LR_P_Bldg1_F6_2	LR_P_Bldg1_F6_3
	TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0
			Criterion 2	0	0	0
			Criterion 3	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass

Building 2 - Test 2 (1989 TM49 design weather file) overheating risk in living rooms

Results for Building 2 - Level 4 living rooms

Level 4 living rooms		Assessment criteria		LR_P_Bldg2_F4_4
	TM52 and BS EN 15251	*Category II*	Criterion 1	0.50
			Criterion 2	0
			Criterion 3	0
	BS EN 15251 Category II			Pass

Results for Building 2 - Level 5 living rooms

Level 5 living rooms		Assessment criteria		LR_P_Bldg2_F5_1	LR_P_Bldg2_F5_2	LR_P_Bldg2_F5_3	LR_P_Bldg2_F5_4
	TM52 and BS EN 15251	*Category II*	Criterion 1	0.58	0	0.15	1.67
			Criterion 2	0	0	0	3
			Criterion 3	0	0	0	0
	BS EN 15251 Category II			Pass	Pass	Pass	Pass

Results for Building 2 - Level 6 living rooms

Level 6 living rooms		Assessment criteria		LR_P_Bldg2_F6_1
	TM52 and BS EN 15251	*Category II*	Criterion 1	0.80
			Criterion 2	0
			Criterion 3	0
	BS EN 15251 Category II			Pass

Building 2 - Test 3 (2003 TM49 design weather file) overheating risk in bedrooms

Results for Building 2 - Level 4 bedrooms

Level 4 Bedrooms		Assessment criteria	BR_P_Bldg2_F4_1	BR_P_Bldg2_F4_2	BR_P_Bldg2_F4_3	BR_P_Bldg2_F4_4	BR_P_Bldg2_F4_5	BR_P_Bldg2_F4_6	BR_P_Bldg2_F4_7	BR_P_Bldg2_F4_8 to 9
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 2 - Level 5 bedrooms

Level 5 Bedrooms		Assessment criteria	BR_P_Bldg2_F5_1	BR_P_Bldg2_F5_2	BR_P_Bldg2_F5_3	BR_P_Bldg2_F5_4	BR_P_Bldg2_F5_5	BR_P_Bldg2_F5_6	BR_P_Bldg2_F5_7	BR_P_Bldg2_F5_8 to 9
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0	0	0	0	0	0
		Criterion 2	0	0	0	0	0	0	0	0
		Criterion 3	0	0	0	0	0	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Results for Building 2 - Level 6 bedrooms

Level 6 Bedrooms		Assessment criteria	LR_P_Bldg2_F6_1	LR_P_Bldg1_F6_2	LR_P_Bldg1_F6_3
TM52 and BS EN 15251	*Category II*	Criterion 1	0	0	0
		Criterion 2	0	0	0
		Criterion 3	0	0	0
BS EN 15251 Category II			Pass	Pass	Pass

Building 2 - Test 3 (2003 TM49 design weather file) overheating risk in living rooms

Results for Building 2 - Level 4 living rooms

Level 4 living rooms		Assessment criteria	LR_P_Bldg2_F4_4
TM52 and BS EN 15251	*Category II*	Criterion 1	1.23
		Criterion 2	3
		Criterion 3	4
BS EN 15251 Category II			Fail

Results for Building 2 - Level 5 living rooms

Level 5 living rooms		Assessment criteria	LR_P_Bldg2_F5_1	LR_P_Bldg2_F5_2	LR_P_Bldg2_F5_3	LR_P_Bldg2_F5_4
TM52 and BS EN 15251	*Category II*	Criterion 1	1.89	1.02	1.09	3.12
		Criterion 2	4	3	3	5
		Criterion 3	5	0	0	9
BS EN 15251 Category II			Fail	Pass	Pass	Fail

Results for Building 2 - Level 6 living rooms

Level 6 living rooms		Assessment criteria	LR_P_Bldg2_F6_1
TM52 and BS EN 15251	*Category II*	Criterion 1	2.32
		Criterion 2	4
		Criterion 3	8
BS EN 15251 Category II			Fail