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Thermal Comfort Analysis

176 Prince of Wales Road

BREEAM 2014

Document information		
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Assessment information		
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Introduction

The proposal comprises the extension of the existing middle and rear gallery buildings to provide additional gallery space for the art gallery. Located within the London Borough of Camden, the development has a total gross internal area of approximately 1,633 m^2.

Please note that only the refurbished side of the building (west side) will be analysed in this report. The east side of the building comprises 100% retained elements, which are not subject to any renovation work. Moreover, the existing building services will essentially be retained. Therefore for the purposes of this Thermal Comfort study the building has been subdivided with the existing unrefurbished part of the building excluded.

Thermal modelling of has been carried out in accordance with CIBSE AM11 "Building Energy and Environmental Modelling" for the whole scheme.

Aim

The aim of this study is to demonstrate compliance with the London Plan's Cooling Hierarchy and BREEAM 2014 R&FO credit Hea 4: Thermal Comfort, thus allowing BREEAM credits to be achieved.

An assessment of the thermal performance of occupied spaces in order to ensure that the building design and services strategy can deliver comfort levels in accordance with the requirements set out in CIBSE Guide A "Environmental Design" has been carried out. In particular this study looks at whether the internal winter and summer temperature ranges will be in line with the recommended comfort criteria in Table 1.5 of the Guide.

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London Plan & BREEAM Hea 4

The following are required to demonstrate compliance with the London Plan and achieve one credit for thermal comfort, part of Health and Wellbeing BREEAM section:

- Thermal modelling has been carried out using software in accordance with CIBSE AM11 Building Energy and Environmental Modelling.
- The software used to carry out the simulation at the detailed design stage provides full dynamic thermal analysis. For smaller and more basic building designs with less complex heating or cooling systems, an alternative less complex means of analysis may be appropriate (such methodologies must still be in accordance with CIBSE AM11).
- The modelling demonstrates that:
  a. For air conditioned buildings, summer and winter operative temperature ranges in occupied spaces are in accordance with the criteria set out in CIBSE Guide A Environmental design 2, Table 1.5; or other appropriate industry standard (where this sets a higher or more appropriate requirement/level for the building type).
  b. For naturally ventilated/free running buildings:
    i. Winter operative temperature ranges in occupied spaces are in accordance with the criteria set out in CIBSE Guide A Environmental design, Table 1.5; or other appropriate industry standard (where this sets a higher or more appropriate requirement/level for the building type).
    ii. The building is designed to limit the risk of overheating, in accordance with the adaptive comfort methodology outlined in CIBSE TM52: The limits of thermal comfort: avoiding overheating in European buildings.
- Where undertaking a Part 4 assessment a competent person (e.g. chartered building services engineer) must assess the suitability of existing building services and controls to identify any changes that may be required as a result of fit-out works (e.g. as a result of changes to internal layout, occupant density, additional equipment that may increase cooling loads etc.)
- For air conditioned buildings, the PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices based on the above modelling are reported via the BREEAM assessment scoring and reporting tool.

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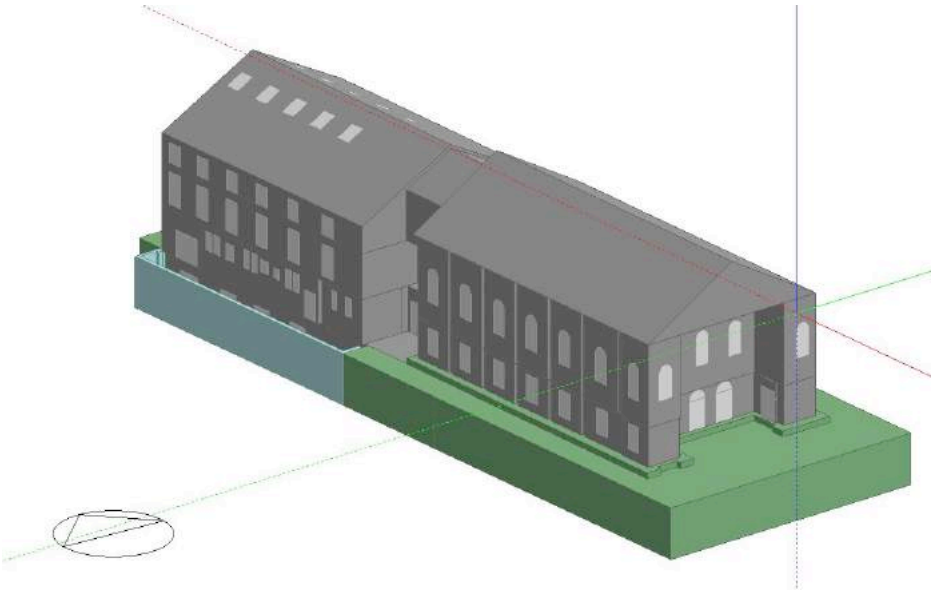
Building Model

A building model was created using Design Builder Energy Plus software, with geometry based on architect's plans and elevations. The building was then analysed using the dynamic simulation method (DSM) to provide hourly temperatures and ventilation rates in each space.



Although the whole building is shown in the 3D model above, please note that only the refurbished side of the building (west side) will be analysed for the purposes of the BREEAM and London Plan in this report. Although the existing east-side of the building is analysed in this report, this is only for the information of the client.

Design Criteria: Building Fabric

Building Element	Part L2A U-value W/m²K	Proposed U-value W/m²K
External wall (existing)	1.60	0.30
External wall (new)	0.28	0.24
Ground floor (existing)	-	0.58
Ground floor (new)	0.22	0.18
Roof (new)	0.18	0.18
Glazing (existing)	-	4.96
Glazing (new)	1.8	1.6
Personnel doors (new)	1.8	1.8

The building air tightness has been modelled as 10 $m^3/(hr.m^2)$ @ 50Pa.

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Design Criteria: Building Services

The refurbished (west-side) part of the scheme will be provided with variable refrigerant flow (VRF) system that will provide space heating and cooling. These areas will also be provided with mechanical and natural ventilation, which can provide an air change rate of up to 5 AC/H.

The existing (east-side) part of the scheme will have a gas boiler providing heating. No cooling or mechanical ventilation will be provided.

Design Criteria: Controls

The controls strategy for the heating and cooling system has been modelled as follows:

Heating set-point	21°C
Heating set-back	18°C
Cooling set-point	24°C
Cooling set-back	26°C

It has to be noted that, in order to ensure an optimal comfort level, the control strategy for the occupied spaces had to be set a very tight configuration, especially for set-back temperatures. The narrow thermal comfort temperature bands and control strategy result in relatively high cooling and heating capacities. Note that there is a trade-off between installed capacity and optimal comfort.

An equal apportionment of the heating and cooling capacities across the floor plate was not adequate to achieve thermal comfort criteria. This is because of the differing heat loss and solar gains for each zone. Consequently, the heating and cooling capacities for each unit room been modelled as indicated in the table below:

Room	Cooling/Heating capacity
AV	4.7 kW
Classroom	17.4 kW
Gallery Storage	56 kW
Kitchenette	2.3 kW
Library	16.9 kW
Performance	75.6 kW
Rear Gallery	49.5 kW

Cooling will be provided by 4 x 56kW VRV condensing systems, the systems will have an energy efficiency rating of 3.01.

Design Criteria Internal Heat Gains

Internal heat gains, from occupants, equipment (e.g. PCs, printers etc) and lighting were estimated based on typical usage patterns applied to different spaces from the main building type (Halls/Theatre/Galleries). Lighting intensity has been modelled at 10 W/m^2

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Simulation Criteria

Design Builder uses Energy Plus format hourly weather data to define external conditions during simulations. For general design purposes a Test Reference Year (TRY) is typically used. It consists of hourly data for twelve typical months, selected from approximately 20-year data sets (typically 1983-2004), and smoothed to provide a composite, but continuous, 1-year sequence of data. They enable the likely energy consumption of buildings to be assessed by simulation under typical weather conditions.

In order to assess thermal comfort of occupied spaces a Design Summer Year (DSY) has been used. It consists of an actual 1-year sequence of hourly data, selected from the 20-year data sets to represent a year with a hot summer. The selection is based on dry bulb temperatures during the period April–September. The year selected is the mid-year of the upper quartile. This enables designers to simulate building performance during a year with a hot, but not extreme, summer. The parameters included in the data sets are: dry bulb temperature (°C); wet bulb temperature (°C); atmospheric pressure (hPa); global solar irradiation (Wh/m2); diffuse solar irradiation (Wh/m2); cloud cover (oktas); wind speed (knots); wind direction (degrees clockwise from North); and Present Weather Code.

Comfort Range

CIBSE Guide A Environmental design, Table 1.5 gives general guidance and recommendations on suitable winter and summer temperature ranges for a range of room and building types. It also indicates the metabolic gain associated with the zone activity with the relative seasonal clothing insulation corresponding to a predicted mean vote (PMV) of ±0.25. The predicted mean vote combines the influence of the air temperature; mean radiant temperature, air movement and humidity with that of clothing and activity level into one value on a thermal sensation scale, where 0 represents a neutral thermal sensation. Spaces occupied only briefly, such as bathrooms, toilets, halls and landings are outside the scope of thermal comfort assessment.
The recommended comfort criteria for specific applications are shown below:

Building/Room Type	Winter Operative Temperature Comfort Range	Summer Operative Temperature Comfort Range
Museum and art galleries	19-21	21-25

Zone Temperature Diagram

In order to demonstrate that summer and winter operative temperatures of the air conditioned spaces are in accordance with the criteria set out in CIBSE Guide A Environmental design, Table 1.5 comply with the criterion 3, a temperature diagram has been produced for each thermal zone of the model and is shown on the following pages for winter and summer.

It has to be noted that this methodology has been applied only to winter for the existing part of the scheme; CIBSE TM 52 outlined the criteria to avoid overheating during summer for naturally ventilated/free running buildings. More details about this methodology can be found from page 17.

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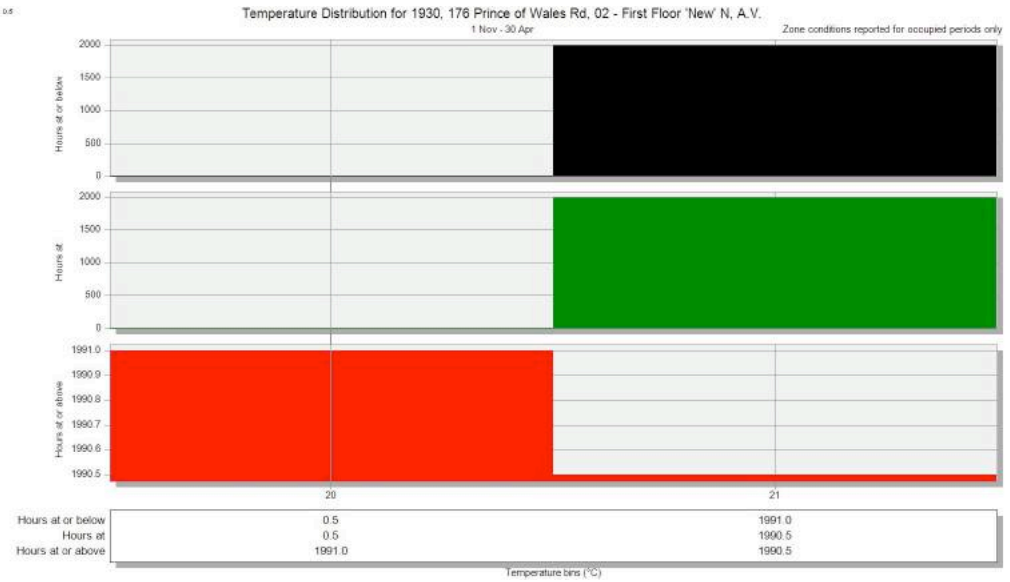
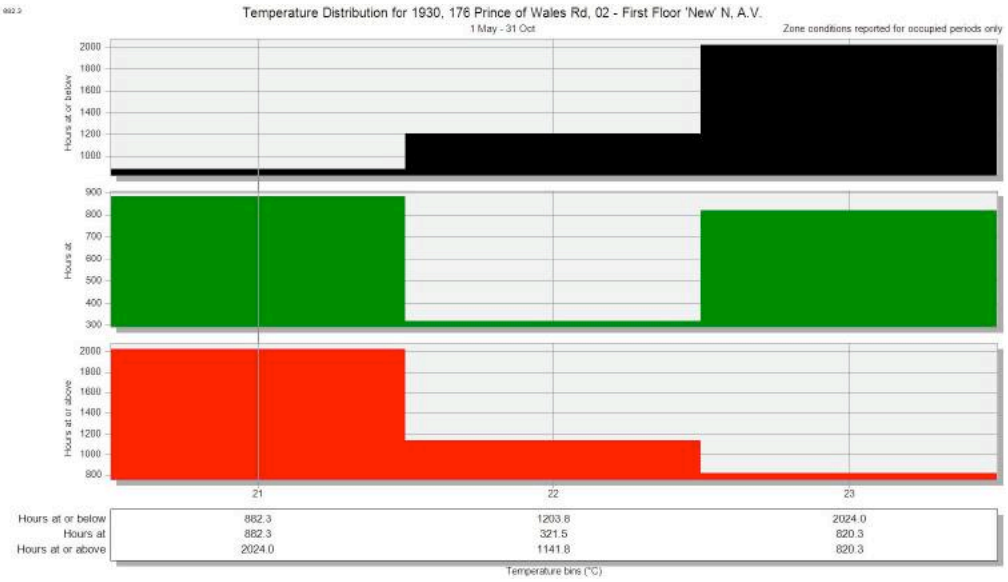
AV
Winter Temperature Distribution



AV
Summer Temperature Distribution



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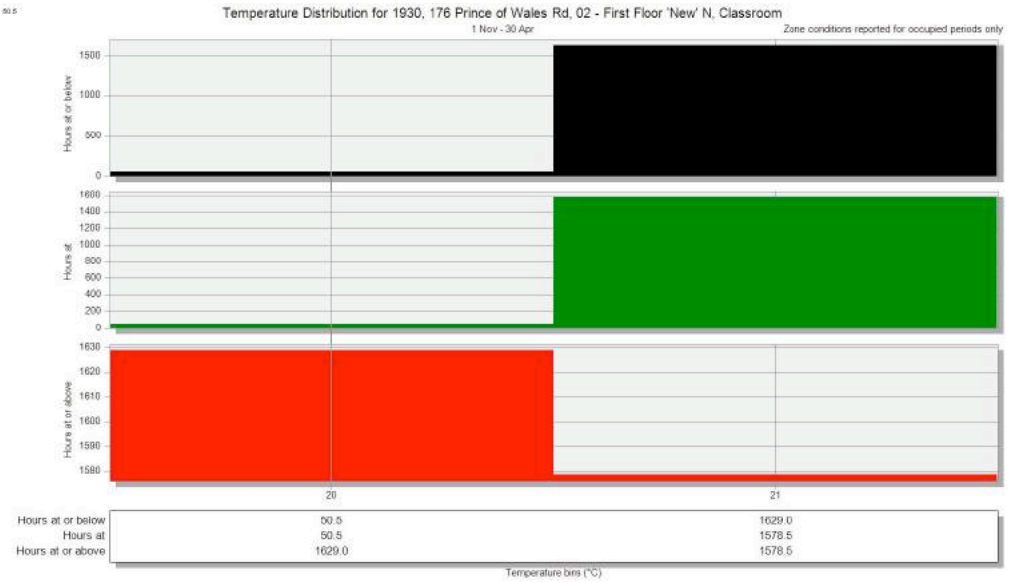
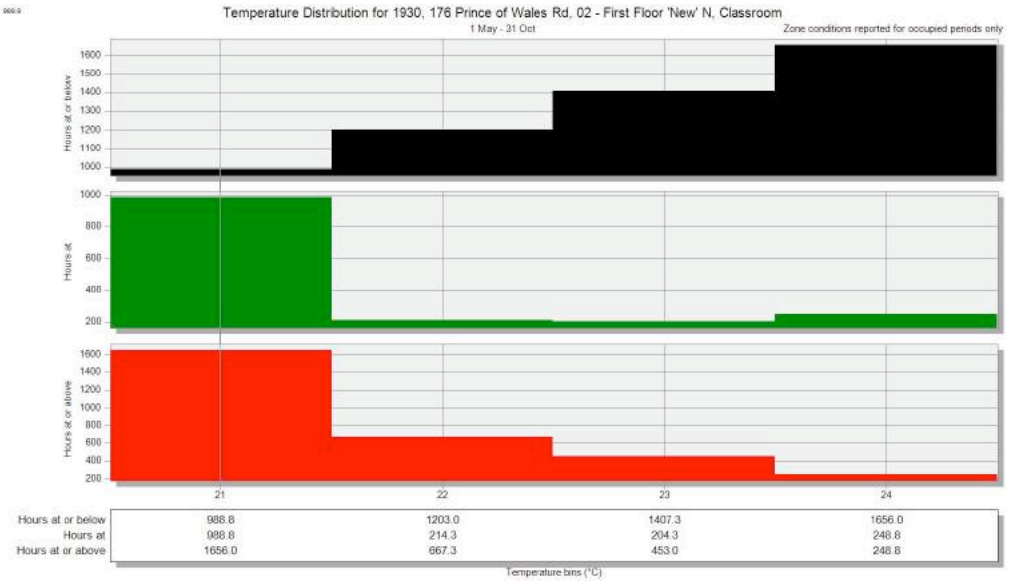
Classroom Winter Temperature Distribution



Classroom Summer Temperature Distribution



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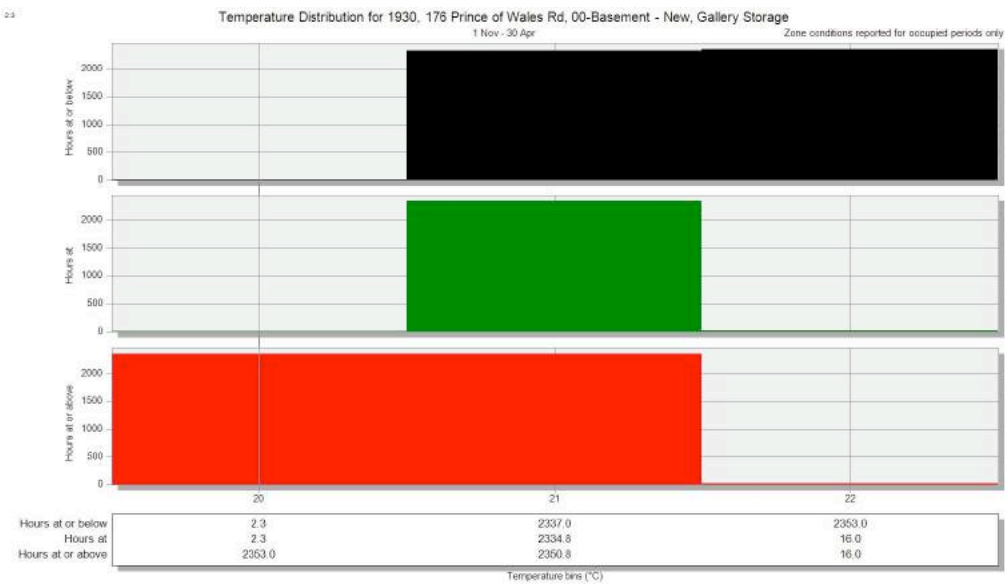
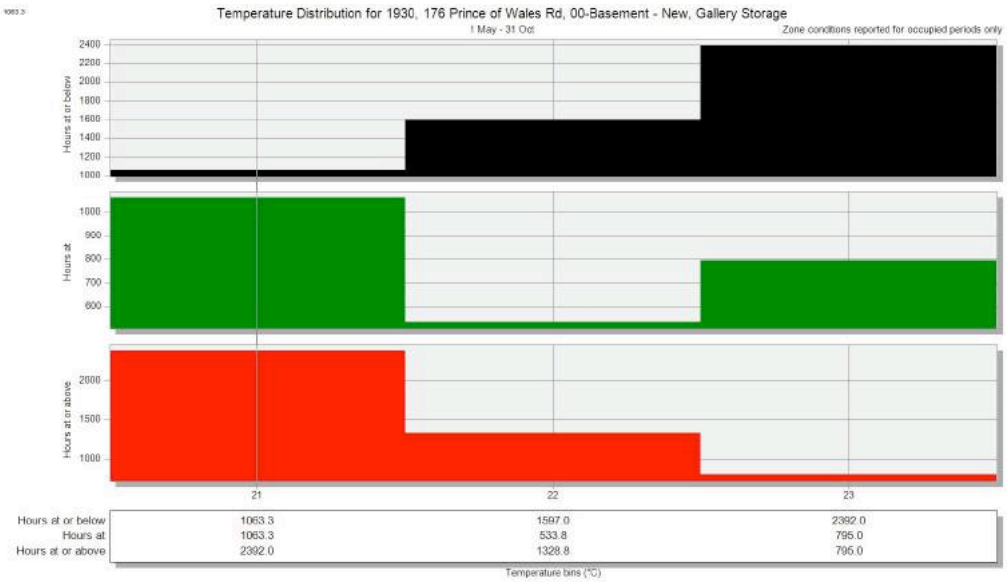
Gallery Storage
Winter Temperature
Distribution



Gallery Storage
Winter Temperature
Distribution



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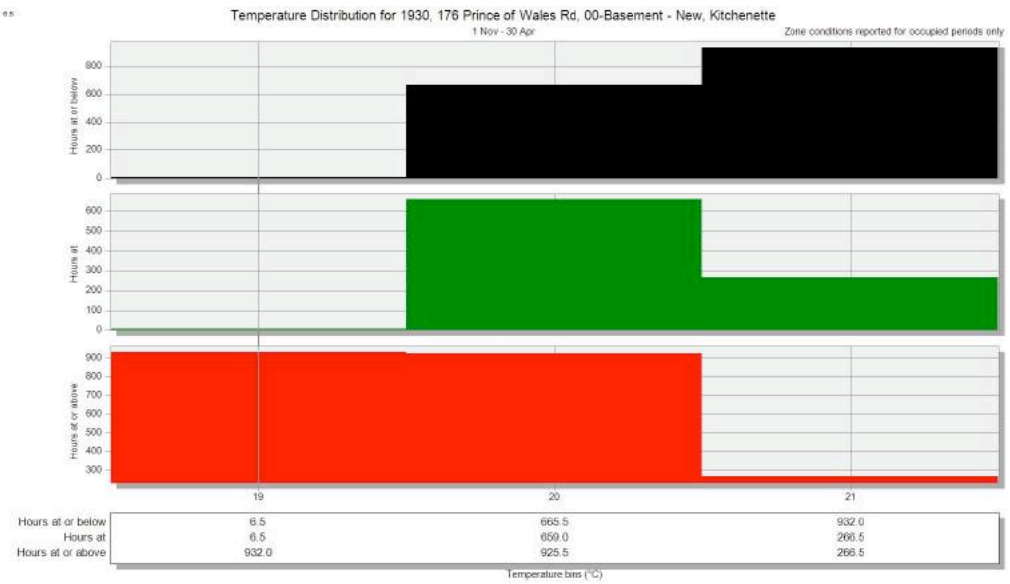
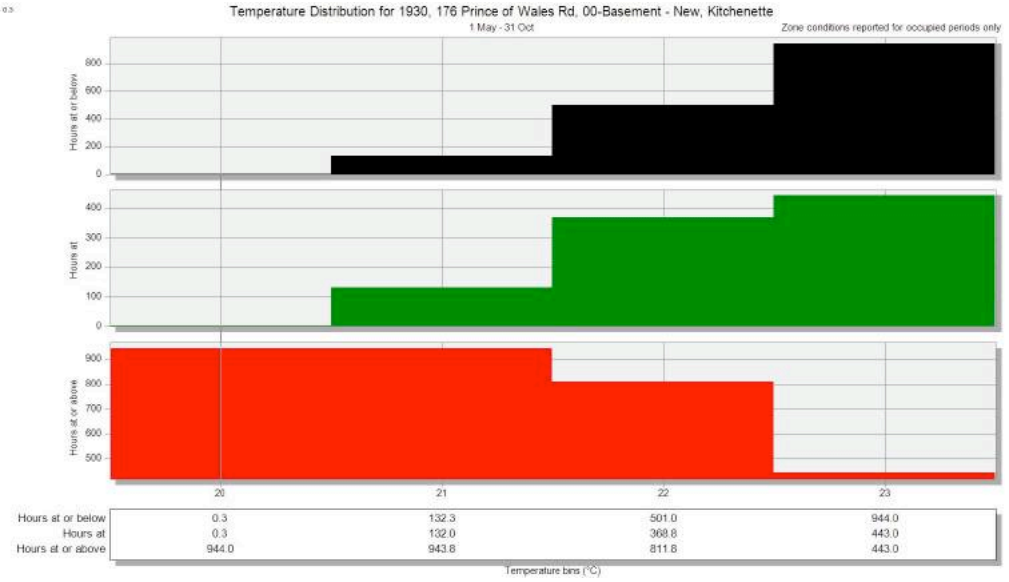
Kitchenette
Winter Temperature
Distribution



	19	20	21
Hours at or below	6.5	665.5	932.0
Hours at	6.5	659.0	266.5
Hours at or above	932.0	925.5	266.5

Kitchenette
Summer Temperature
Distribution



	20	21	22	23
Hours at or below	0.3	132.3	501.0	944.0
Hours at	0.3	132.0	368.8	443.0
Hours at or above	944.0	943.8	811.8	443.0

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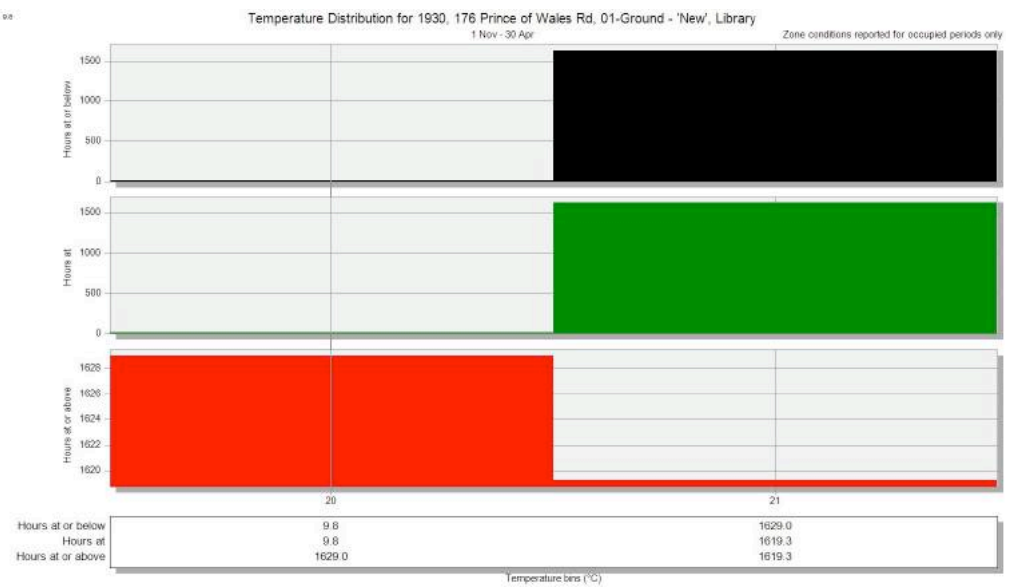
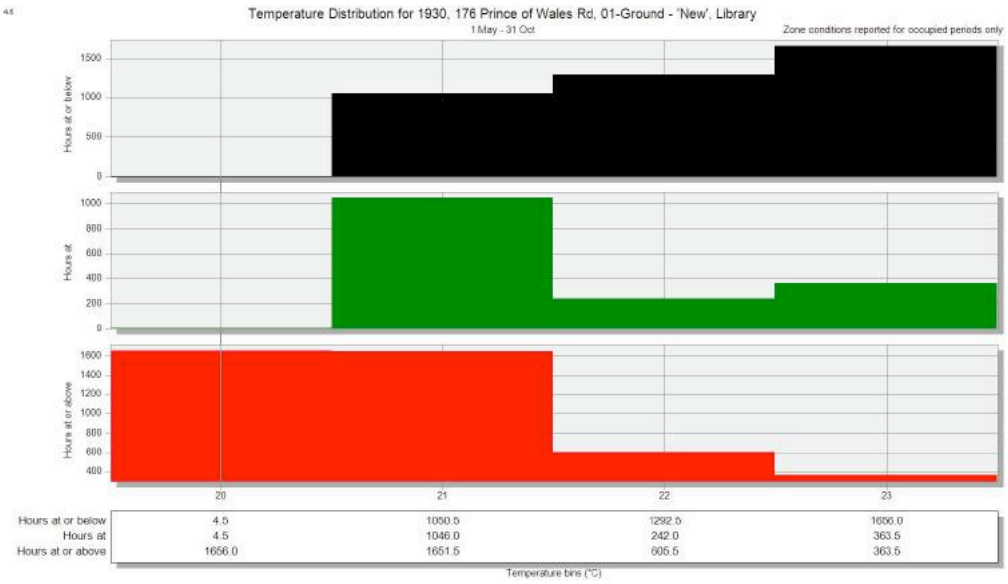
Library
Winter Temperature Distribution



Library
Summer Temperature Distribution



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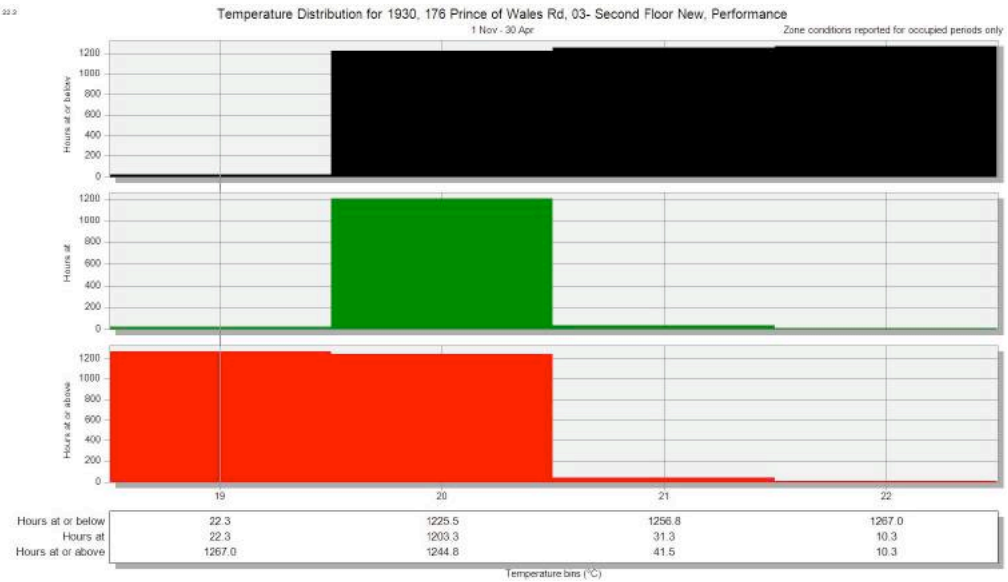
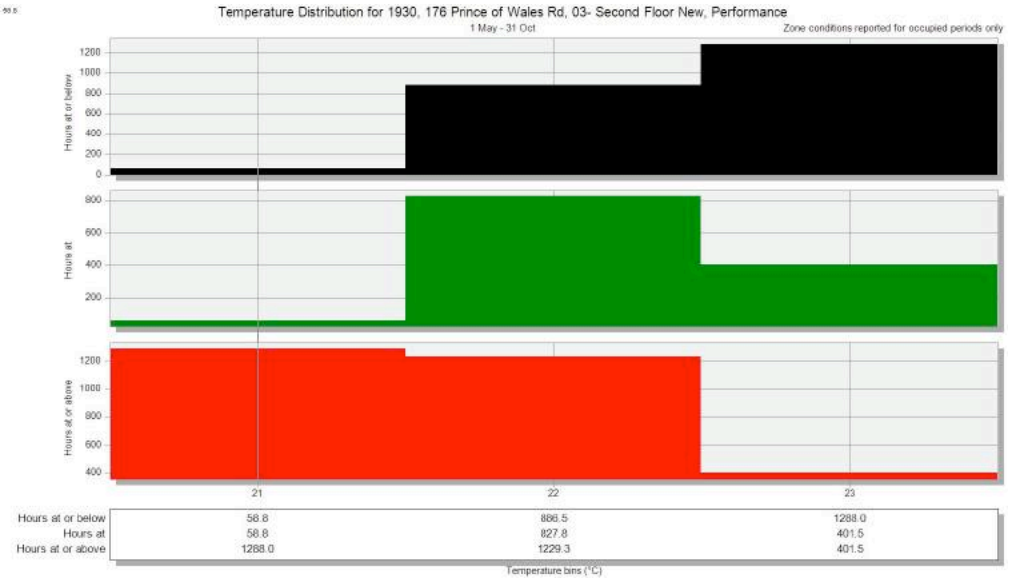
Performance
Winter Temperature Distribution



Performance
Summer Temperature Distribution



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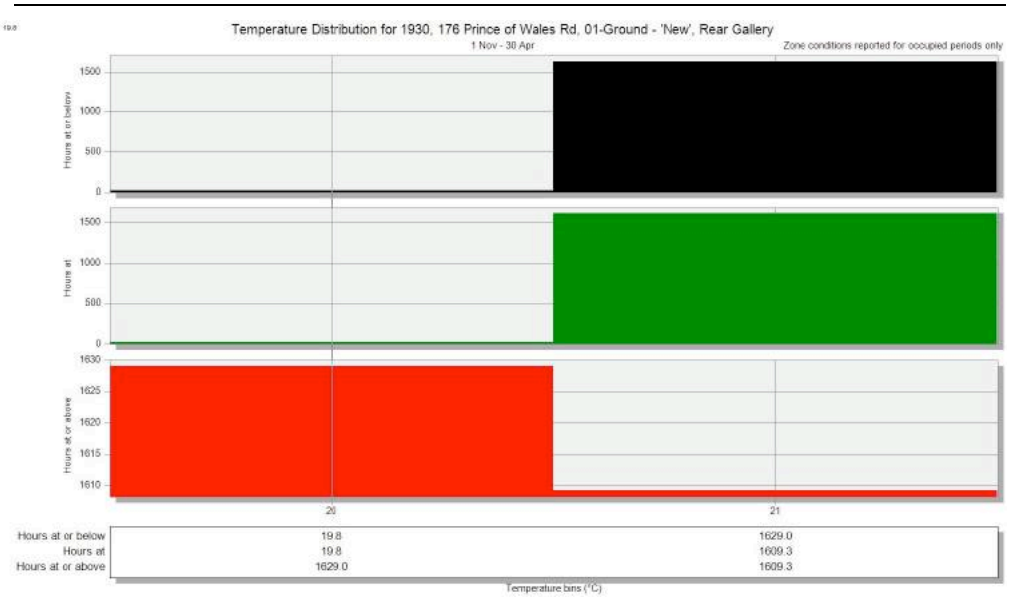
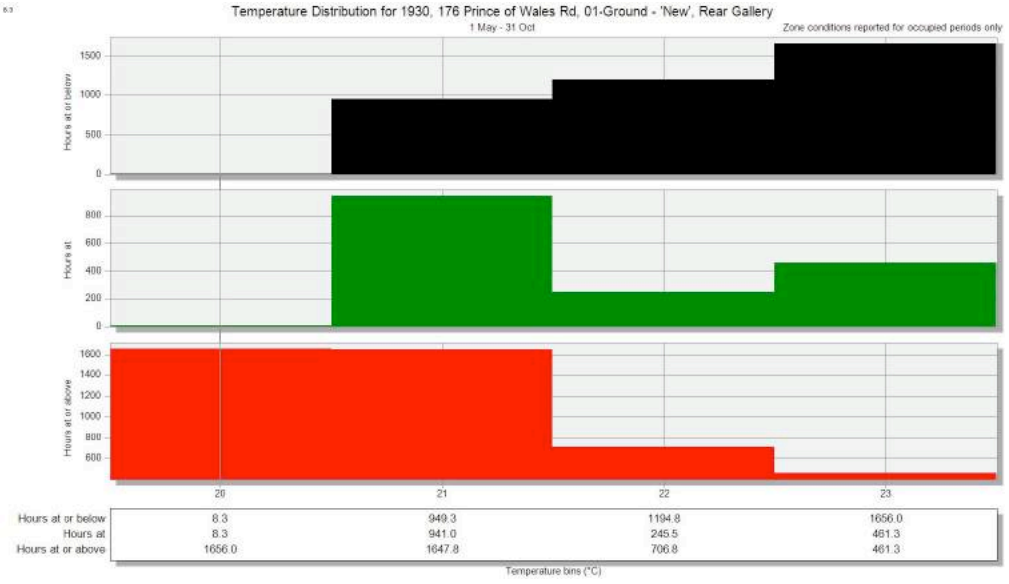
Rear Gallery
Winter Temperature
Distribution



Rear Gallery
Summer Temperature
Distribution



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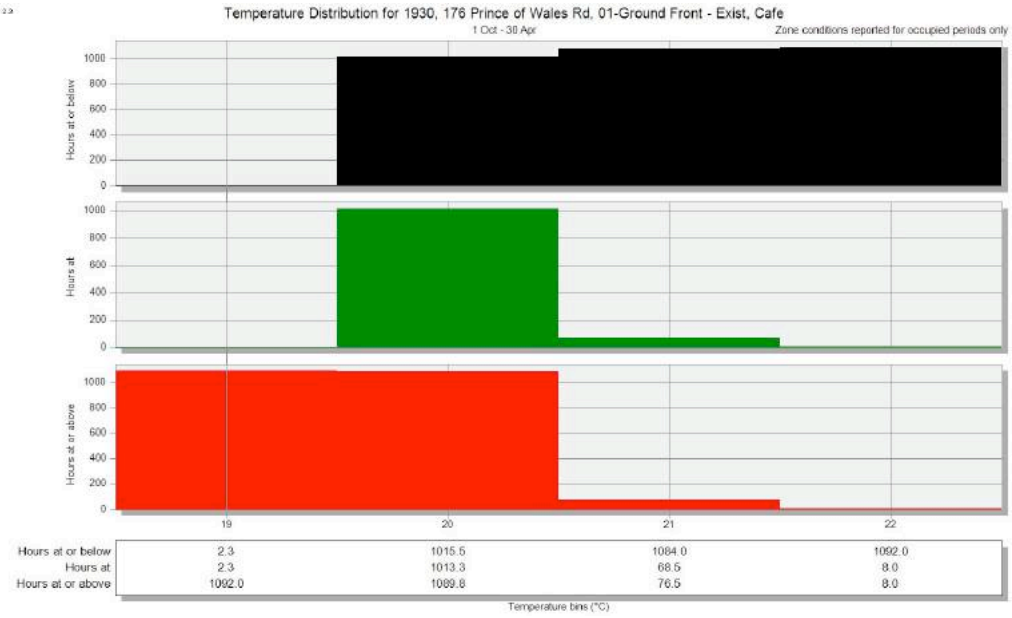
Book Shop (Existing part)
Winter Temperature Distribution

Café (Existing part)
Winter Temperature Distribution



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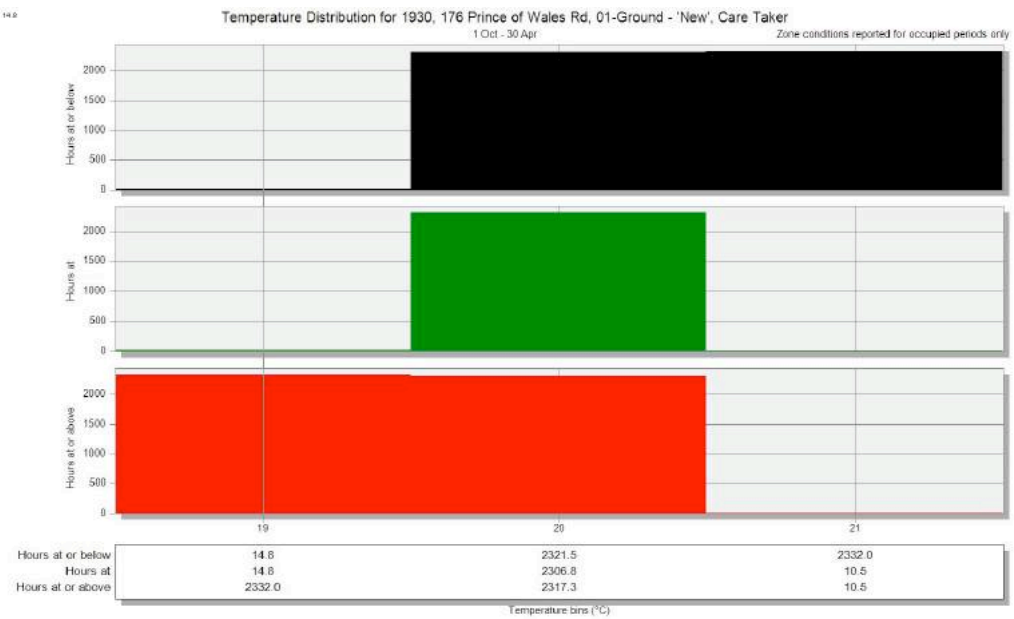
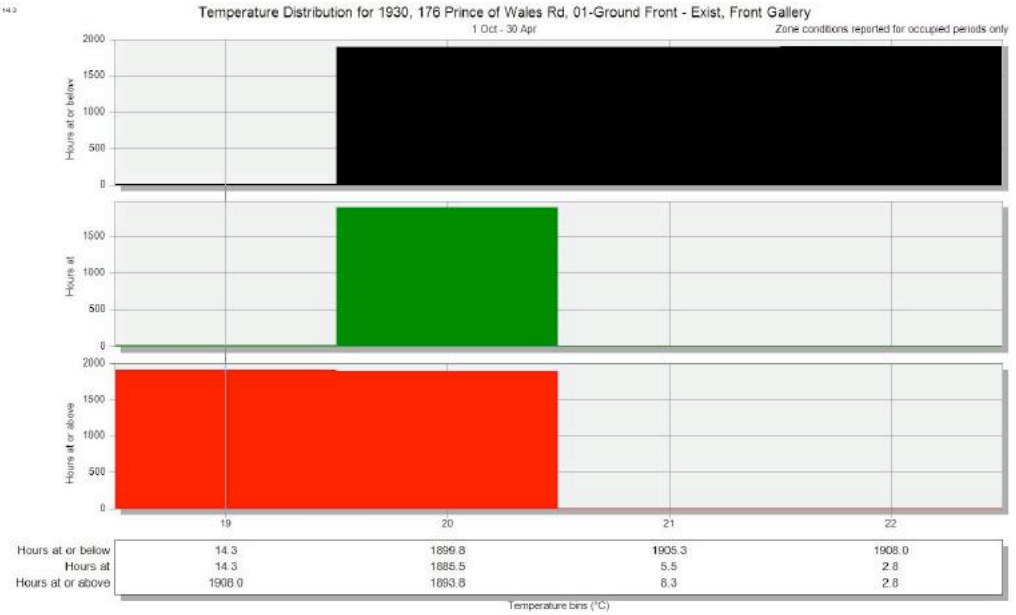
Care Taker (Existing part) Winter Temperature Distribution



Front Gallery (Existing part) Winter Temperature Distribution



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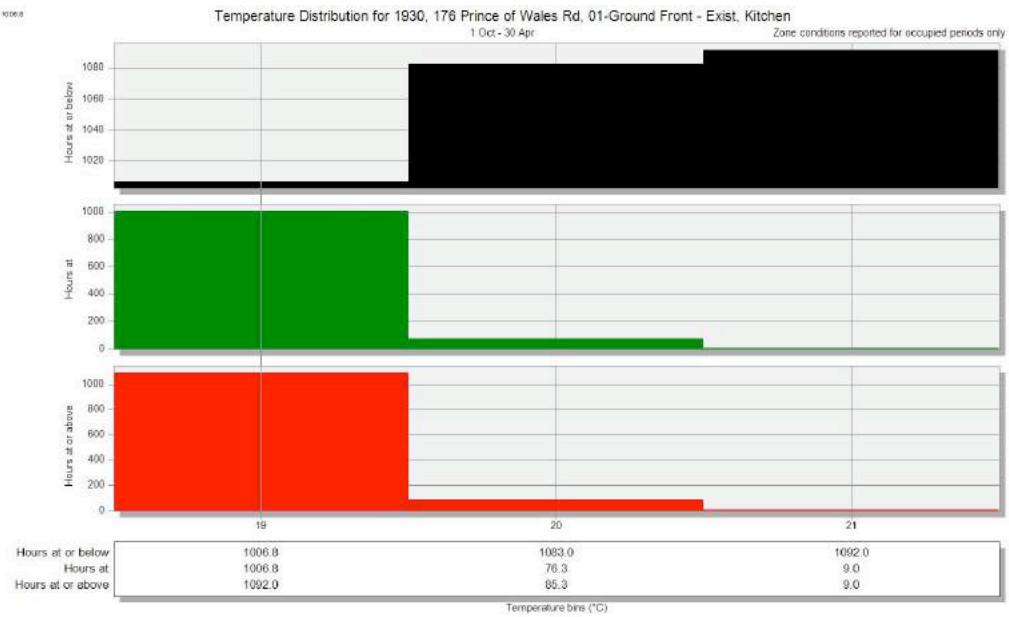
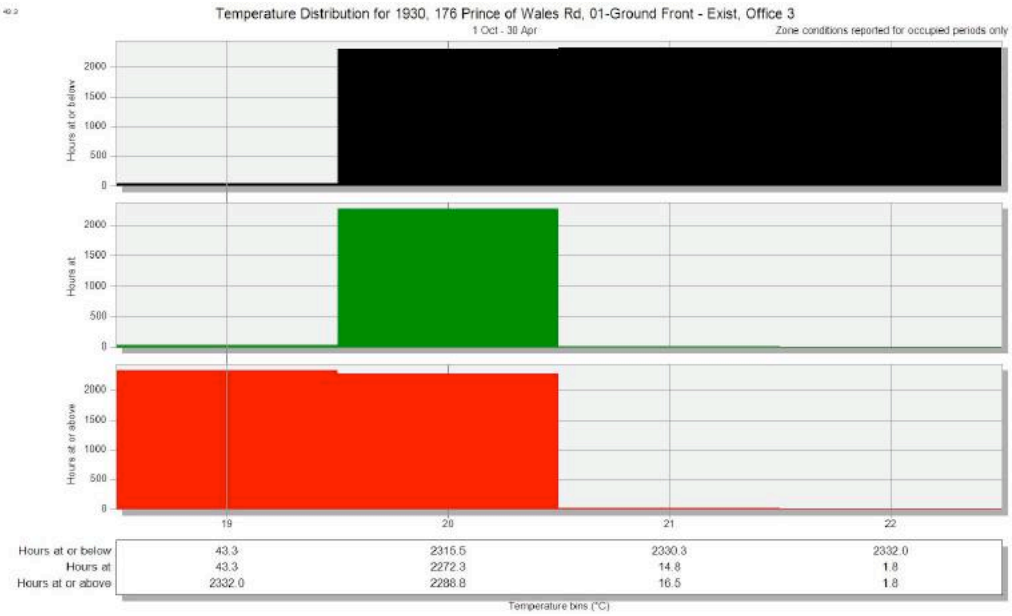
Kitchen (Existing part) Winter Temperature Distribution



Office 3 (Existing part) Winter Temperature Distribution



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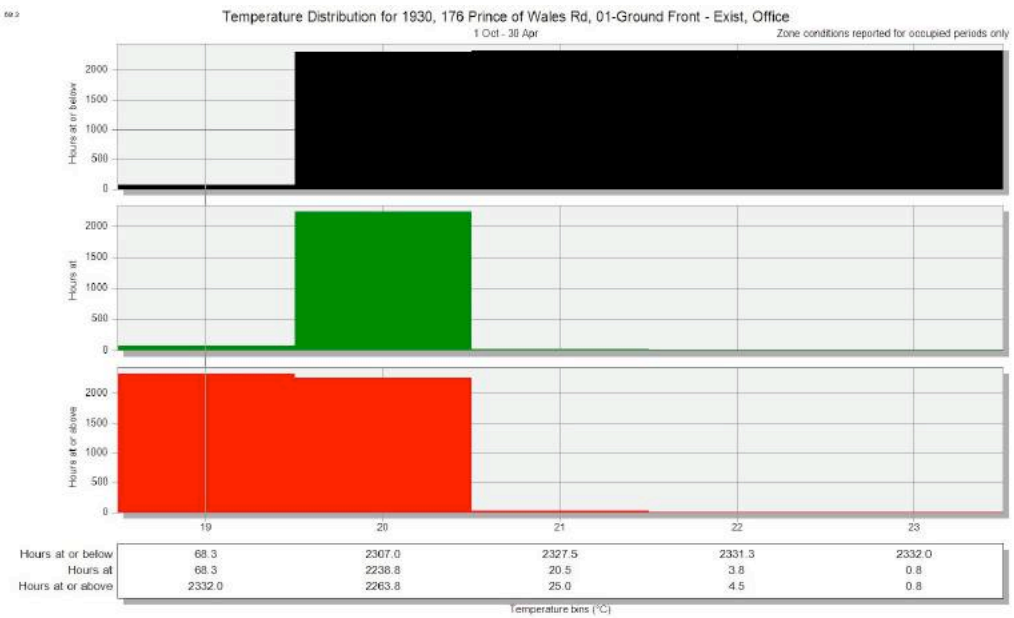
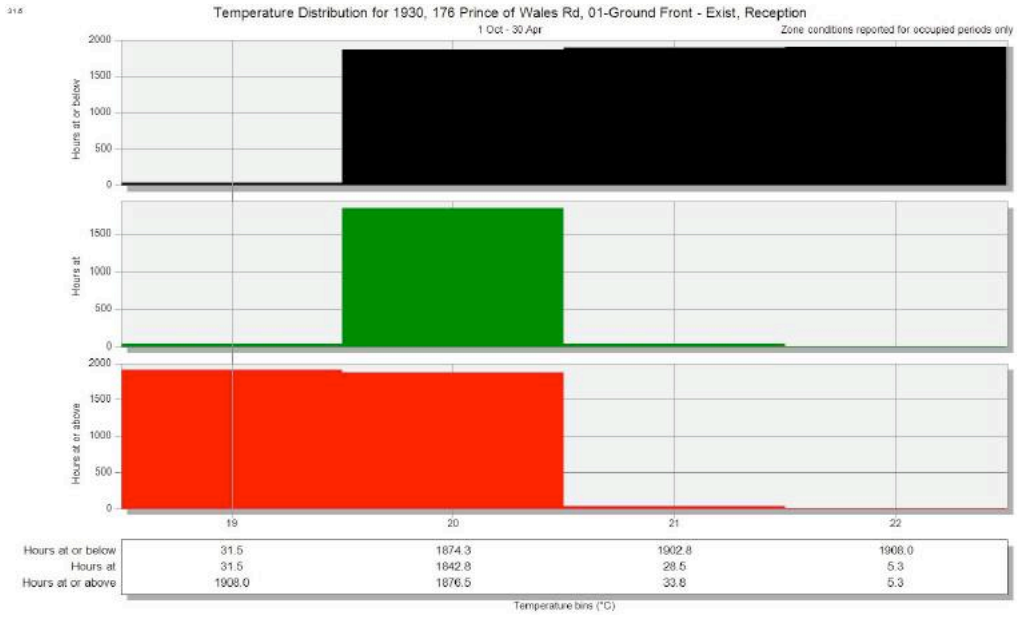
Office (Existing part) Winter Temperature Distribution



	19	20	21	22	23
Hours at or below	68.3	2307.0	2327.5	2331.3	2332.0
Hours at	68.3	2238.8	20.5	3.8	0.8
Hours at or above	2332.0	2263.8	25.0	4.5	0.8

Reception (Existing part) Winter Temperature Distribution



	19	20	21	22
Hours at or below	31.5	1874.3	1902.8	1908.0
Hours at	31.5	1842.8	28.5	5.3
Hours at or above	1908.0	1876.5	33.8	5.3

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Refurbished (west-side) of scheme
Summary of results:

Zone	Comfort Range		Hours Below Range	Hours Above Range	Occupied Hours	% Out of Range	
	Summer	Winter					
AV	21-25		0	0	4,015	0.00 %	✔
		19-21	0	0			
Classroom	21-25		0	0	3,285	0.00 %	✔
		19-21	0	0			
Gallery Storage	21-25		0	0	4,745	0.00 %	✔
		19-21	16	0			
Kitchenette	21-25		0.3	0	1,876	0.00 %	✔
		19-21	0	0			
Library	21-25		4.5	0	3,285	0.00 %	✔
		19-21	0	0			
Performance	21-25		0	0	2,555	0.00 %	✔
		19-21	0	10.3			
Rear Gallery	21-25		8.3	0	3,285	0.00 %	✔
		19-21	0	0			

Existing (east-side) part of scheme
Summary of results:

Zone	Comfort Range		Hours Below Range	Hours Above Range	Occupied Hours	% Out of Range	
	Summer	Winter					
Book Shop	N/A				2,332	0.00 %	✔
		19-21	0	0			
Cafe	N/A				1,092	0.01 %	✔
		19-21	0	8			
Care Taker	N/A				2,332	0.00 %	✔
		19-21	0	0			
Front Gallery	N/A				1,908	0.00 %	✔
		19-21	0	2.8			
Kitchen	N/A				1,092	0.00 %	✔
		19-21	0	0			
Office 3	N/A				2,332	0.00 %	✔
		19-21	0	1.8			
Office	N/A				2,332	0.00 %	✔
		19-21	0	4.5			
Reception	N/A				1,908	0.00 %	✔
		19-21	0	5.3			

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Criteria for Defining Overheating

According to the CIBSE Guide A – Environmental Design (2015) and CIBSE TM 52 – The limits of thermal comfort: avoiding overheating in European buildings (2013), to reduce the risk of overheating the building/room has to comply with the following three criteria:

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

Baseline Scenario Overview of Results

The graph on the following pages show the outdoor and indoor temperature of the front gallery, this is a representative example for the whole scheme. The graph shows the T_{max}, which is the upper range of thermal comfort, and T_{upp}, which is the absolute upper limit of thermal comfort.

In order to comply with the overheating criteria the building must comply with the following requirements.

- Criterion 1 - The percentage of hours with temperature more than the T_{max} should be less than 3%.
- Criterion 2 - The weighted exceedance shall be less than or equal to 6 in any one day
- Criterion 3 - No occupied hour of the building shall exceed the absolute upper limit temperature. ($T_{upp} = T_{max} + 4K$)

The results for all existing (east-side) parts of the scheme show that the scheme fails to comply with the criteria outlined above. The ground floor Front Gallery exceeds the 3% limit of hours where the operative temperature is higher than the maximum temperature. A summary table showing the obtained results for each room of the scheme is shown on the following page.

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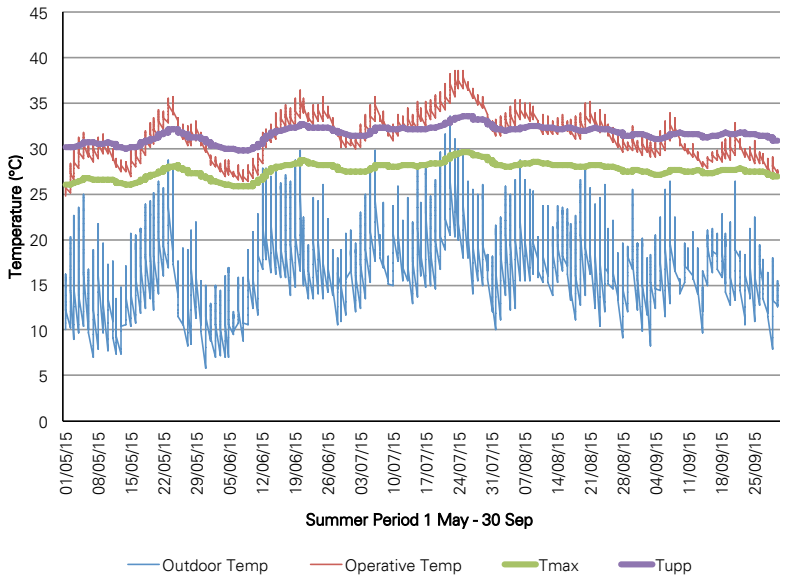
Front Gallery Temperature Graph



Room	Criterion 1	Criterion 2	Criterion 3	Compliance
Front Gallery	3.1%	10.78	0	FAIL

Summary of results

Room	Criterion 1	Criterion 2	Criterion 3	Compliance
Cafe	8.7%	28.30	1	FAIL
Offices	3.7%	16.54	0	FAIL
Reception	3.4%	17.32	0	FAIL
Kitchen	4.7%	22.09	0	FAIL
Front Gallery	3.1%	10.78	0	FAIL
Office 3	3.1%	18.53	0	FAIL
Book Shop	2.9%	14.30	0	PASS
Caret Taker	2.9%	17.15	0	PASS

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Conclusions

The results of thermal modelling demonstrate that the refurbished (west-side) part of the scheme complies with London Plan, CIBSE Guide A and BREEAM requirements.

The existing (east-side) part of the scheme is unable to comply with the CIBSE requirements as it is does not feature comfort cooling.

From the results of this analysis, the following conclusions can be drawn:

- All occupied spaces meet the thermal comfort requirements (except for summer overheating for the existing part of the scheme).
- As defined by CIBSE AM11 the site provides adequate thermal comfort in accordance with CIBSE Guide A.
- Thermal modelling results demonstrate that thermal comfort levels in occupied spaces meet the category B requirements for both PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices as shown on the image below.