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Temporary Accommodation - Highgate School, London, N6 4NY

BB101 Overheating Report

UK26032

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1. EXECUTIVE SUMMARY

Zenon has undertaken a BB101 compliance assessment for Highgate School to evaluate the proposed temporary school block development in London, N6 4NY. The assessment aims to determine whether the proposed development meets the BB101 compliance criteria relating to overheating and indoor air quality.

This report summarises the assessment methodology and presents the results of the thermal comfort and indoor air quality analysis. It also identifies any passive mitigation measures required to maintain acceptable levels of thermal comfort and air quality within the assessed spaces. The assessment uses occupancy profiles and operating schedules developed in accordance with CIBSE guidance and the anticipated building occupancy defined by BB101. The assessment has also been undertaken in accordance with the principles of the London Plan Cooling Hierarchy and Haringey Overheating Guidance, prioritising passive and natural ventilation measures before considering mechanical ventilation and cooling strategies.

Following a detailed assessment of the site, proposed building, and available measures to achieve BB101 compliance, the following approach has been adopted:

- Building envelope U-values and g-values have been assigned in accordance with the proposed fabric specifications developed for Part L compliance.
- Internal gains and operating schedules have been assigned based on the room type and relevant CIBSE guidance, including occupancy, lighting, and equipment gains.
- Thermal modelling has been undertaken using London weather data and all three Design Summer Year scenarios to assess the building under different summer weather conditions
- A baseline model has initially been assessed to determine whether the proposed building can achieve BB101 compliance without the introduction of additional mitigation measures
- As the baseline model did not achieve the required compliance criteria, an updated ventilation strategy has been proposed to improve thermal comfort and IAQ performance and achieve compliance under all three weather scenarios.

2. BUILDING BULLETIN 101 (BB101) DESIGN CRITERIA

2.1. Introduction

Building Bulletin 101 (BB101) is a guidance document issued by the Department for Education (DfE) in the UK. It sets out requirements for ventilation, thermal comfort, and indoor air quality in educational buildings in England. The current version, BB101:2018, was published in 2018 and adopts a dynamic, adaptive approach to assessing thermal comfort based on the methodology provided in CIBSE TM52.

The guidance applies to both new-build projects and refurbishments of existing educational facilities funded by the DfE. Compliance with BB101 forms part of the technical requirements for obtaining project approval.

2.2. Air Quality Requirements (IAQ) and Ventilation Requirements

BB101 specifies maximum carbon dioxide (CO₂) concentration levels as an indicator of adequate ventilation. The required limits depend on the ventilation strategy adopted:

- Natural ventilation:
 - The average daily CO₂ concentration should not exceed 1,500 ppm in teaching and learning spaces.
 - The CO₂ concentration should not exceed 2,000 ppm for more than 20 minutes during the teaching day.
- Mechanical ventilation or hybrid system operating in mechanical mode:
 - The average daily CO₂ concentration should not exceed 1,000 ppm in teaching and learning spaces.
 - The CO₂ concentration should not exceed 1,500 ppm for more than 20 minutes during the teaching day.

Regardless of the ventilation strategy, CO₂ concentrations are assessed at seated head height over the continuous period between the start and end of teaching on each day.

The guidance also specifies minimum ventilation rates per occupant to maintain adequate indoor air quality:

- During normal operating hours, a minimum ventilation rate of 5 l/s per person should be provided to satisfy the minimum ventilation requirement;
- When system reaches its maximum capacity, the ventilation rate should be capable of increasing to 8 l/s per person to maintain the required indoor air quality.

2.3. Overheating Assessment Methodology

The overheating assessment methodology used to evaluate the thermal comfort of students during occupied hours depends initially on the ventilation mode under which the building is operating. For buildings operating in natural ventilation mode, BB101 adopts the CIBSE TM52 methodology for assessing overheating risk.

2.3.1. TM52 CIBSE – Natural Mode

The TM52 assessment compares the predicted internal room temperature against a maximum acceptable temperature derived from the running mean outdoor temperature. The running mean temperature gives greater

weighting to temperatures from more recent days, as these have a greater influence on occupants perceived thermal comfort and their adaptation to prevailing outdoor conditions.

Thermal comfort is assessed against three TM52 criteria, with a space considered to pass the assessment when at least two of the three criteria are satisfied. The three criteria are described below:

Hours of Exceedance

This criterion assesses the number of hours (H_e) during which the temperature difference (between actual operative temperature and maximum allowed temperature) is greater than or equal to one degree during the period of May to September inclusive shall not be more than 3% of occupied hours.

Threshold temperature exceeded by one degree $\leq 3\%$ of occupied hours

Daily Weighted Exceedance

This criterion assesses the severity of overheating, the weighted exceedance (W_e) shall be less than or equal to 6 degree-hours in any one day.

Daily weighted exceedance (degree-hours) ≤ 6

Upper Limit Temperature

Criterion 3 sets an absolute maximum threshold for the indoor operative temperature for which the temperature difference between indoor operative temperature and maximum allowed temperature shall not exceed four degrees.

Temperature $\leq$ upper limit

2.3.2. PMV Index – Mechanical Mode

For spaces operating in mechanical ventilation mode, including the mechanical mode of hybrid ventilation systems, BB101 requires compliance with the thermal comfort criteria set out in BS EN ISO 7730. This standard defines the Predicted Mean Vote (PMV) index as a quantitative method for assessing the thermal comfort of occupants. PMV is not a direct physical measurement; instead, it is an index developed from evaluations of occupants' thermal comfort and is based on six parameters: air temperature, mean radiant temperature, air velocity, relative humidity, metabolic rate, and clothing insulation.

The PMV scale ranges from -3 to +3, where -3 represents a feeling of cold, 0 represents thermal neutrality, and +3 represents a feeling of heat.

For BB101 assessments, the acceptable PMV range for new buildings is +0.5. It is important to note that the assessment is based on the entire occupied period. If the calculated PMV falls outside the acceptable range for even a single hour, the space is considered to fail the thermal comfort assessment.

2.4. Analysis Period and Timeframe

The overheating assessment is conducted over the period from 1 May to 30 September, covering working days only (Monday to Friday) and the occupied period between 09:00 and 16:00. A lunch break is taken into account from 12:00 to 13:00, during which internal gains for teaching and learning spaces are set to a minimum.

Although the school is not expected to be occupied for a significant portion of the summer period, the BB101 methodology requires the building to be treated as fully operational throughout the assessment period. This approach ensures that the assessment considers the worst-case overheating scenario that could occur within the building.

3. DETAILED SITE ANALYSIS

The site assessed in this report is Highgate School, located in London. The existing school comprises three buildings that are scheduled for refurbishment, requiring all three buildings to be fully vacated for the duration of the works. To accommodate students displaced from these buildings, a new temporary modular teaching block is proposed on the southern end of the synthetic playing fields, located to the east of Bishopswood Road. The development includes the necessary access pathways, utility connections, and connection to the existing sewage system.

The temporary teaching block is intended to remain in use for the duration of the refurbishment and is to be removed once the works to the existing school buildings have been completed. The temporary school has a total gross floor area of approximately 2,314 m² and comprises laboratory classrooms, preparation rooms, modern foreign language (MFL) rooms, as well as offices and staff rooms for teachers.

During the site analysis, all available architectural drawings, including floor plans and sections, were reviewed. The assessment also considered the building orientation and surrounding features.

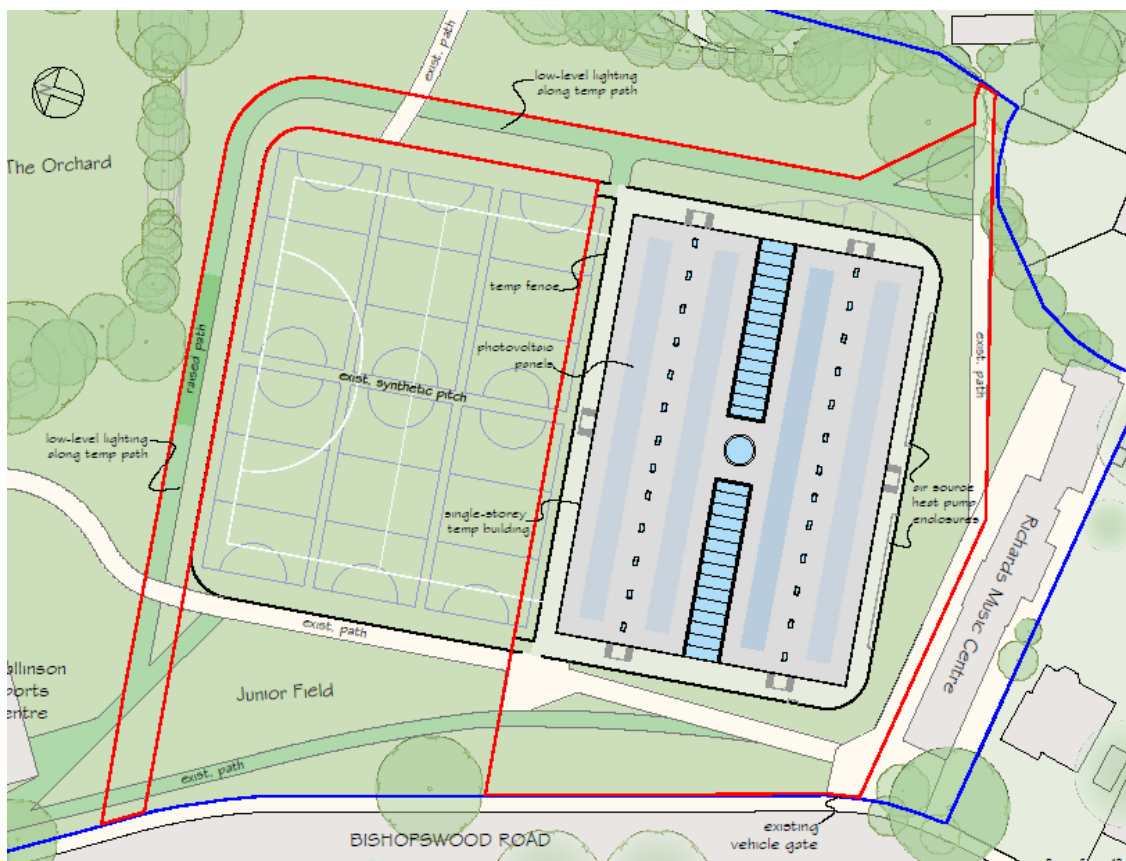


Figure 1: Temporary modular teaching block proposed site plan

4. 3D MODELING

To carry out dynamic thermal modelling and accurately assess compliance with BB101, a detailed 3D representation of the building must first be developed. The model is created using architectural floor plans and sections as the primary reference.

For this assessment, the IES VE software suite was used. The building geometry was created using the ModelIT module, which was also used to model local shading features, adjacent buildings, and the rooftop photovoltaic (PV) panels. Several additional modules were utilised to perform the thermal analysis of the building, including SunCast for solar shading analysis, Apache and ApacheHVAC for dynamic thermal simulation and HVAC system modelling, and MacroFlo for the simulation of multi-zone air movement and natural ventilation.

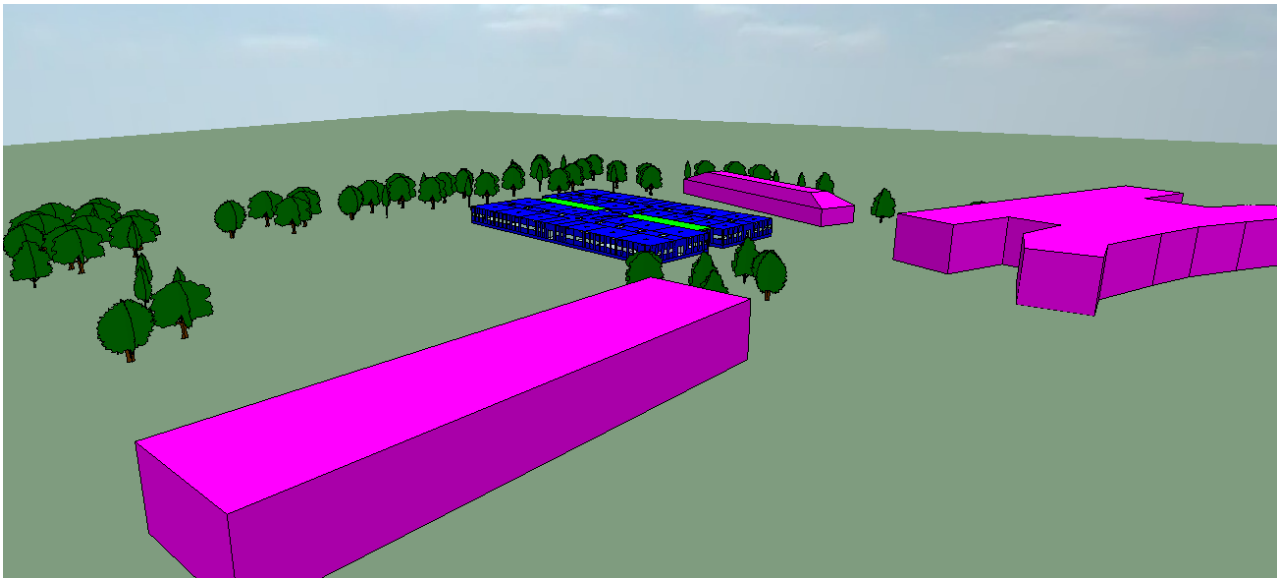


Figure 2: Building model in IES VE

5. DEVELOPMENT FEATURES

5.1. Building Fabric

The following building elements have been assumed as per the fabric specification for Part L 2021, that are specific to modular building structures. The U-Values, thermal mass and g-values have been modelled as follows and are presented in Table 1.

Table 1: Envelope performance per element

Building Element	Performance
External Wall	U=0.12 W/m ² K
Ground	U=0.10 W/m ² K
Roof	U=0.10 W/m ² K
Window	U=1.4 W/m ² K, g-value=0.4
Roof light	U=1.4 W/m ² K, g-value=0.4
Pedestrian Door	U=1.4 W/m ² K
Air Permeability	5.0 m ³ /m ² /hr @50 Pa

5.2. Weather Data

The dynamic thermal modelling approach requires the use of appropriate weather data to ensure compliance with BB101. The IES VE software incorporates CIBSE weather files, which are used to drive the thermal simulation process. CIBSE provides two main types of weather files: TRY (Test Reference Year) and DSY (Design Summer Year).

TRY weather files are constructed by combining representative “typical” months derived from historical climate data into a single synthetic year. These files are generally used for standard energy assessments but are not suitable for BB101 compliance analysis and are therefore not applied in this context.

DSY weather files, on the other hand, are specifically developed to test a building’s thermal performance under high-stress summer conditions. Unlike TRY files, which represent typical conditions, DSY files are designed to reflect statistically hot summer periods in order to assess overheating risk.

CIBSE provides three DSY variants to capture different severities and durations of hot weather events:

- DSY1 – Moderately warm summer conditions
- DSY2 – Short, intense heatwave conditions
- DSY3 – Prolonged, sustained heatwave conditions

Both TRY and DSY weather files are available for 14 locations across the UK. For the BB101 design criteria assessment at Highgate School, all three Design Summer Year weather files will be used to assess the building under different summer weather conditions. This approach provides a more comprehensive understanding of the building's thermal performance and ensures that its performance is assessed across all three weather scenarios.

5.3. Noise, Pollution or Security Constraints

There are no significant noise pollution, external air quality, or safety and security constraints associated with the assessed site. As a result, there are no significant factors restricting window opening or limiting the effectiveness of natural ventilation within the building.

5.4. Baseline Ventilation Strategy

5.4.1. Natural Ventilation – Openable Windows

The baseline ventilation strategy consists solely of partially openable windows, which provide the only and primary means of natural ventilation to the assessed spaces. As the windows are only partially openable, 25% of the equivalent window area is considered available for natural ventilation when the windows are fully open.

During the simulation, the windows are programmed to start opening when the internal room air temperature reaches 21°C and to be fully open at 24°C. The windows are not permitted to open when the external air temperature is higher than the internal room temperature, and natural ventilation is only enabled when the external air temperature is above 15°C.

As there is no mechanical ventilation in the baseline scenario, the building is assessed against the CIBSE TM52 criteria for thermal comfort. In addition, the required IAQ is maintained in accordance with the limits applicable to naturally ventilated spaces.

Internal doors are also modelled as fully open during the lunch break to more accurately represent the expected building operation during occupied hours. This allows cross-flow ventilation between the occupied spaces and the corridor during the break period.

External doors are assumed to remain fully closed during both occupied and unoccupied periods.

5.5. Internal Gains

5.5.1. Occupancy Gains

As previously mentioned, occupancy in accordance with BB101 is defined from 09:00 to 16:00, with a one-hour lunch break during this period. The occupancy for each room type is determined based on the applicable occupancy density, expressed in m²/person.

It is also important to note that the internal gains generated by children are lower than those generated by adults, with gains from a child assumed to be approximately 65% of those generated by an adult male. As a result, the occupancy gains for pupils within learning spaces are approximately 50 W sensible and 30 W latent per person. Circulation, washrooms and storage rooms are not considered to be occupied. The assumed occupancy densities and internal gains for each room type are presented in Table 2.

Table 2: Occupancy gains for each room type

Room Type	Occupancy density (m2/person)	Gains (W/person)		Profile
		Sensible	Latent	
MFL	2	50	30	100% gain from 09:00 to 12:00 & 13:00 to 16:00 0% gain from 12:00 to 13:00
Laboratory	3	50	30	
Office/Staff	10	75	55	
Prep Room	10	75	55	

5.5.2. Lighting Gains

The modular temporary school is equipped with low-energy LED lighting incorporating presence detection and daylight dimming controls. This results in a relatively low lighting power density, ranging from approximately 3–6W/m² depending on the room type. The assumed lighting power density and corresponding lighting profiles for each room type are presented in Table 3.

Table 3: Lighting gains for each room type

Room Type	Lighting density (W/m2)	Profile
MFL	4	100% gain from 09:00 to 12:00 & 13:00 to 16:00 0% gain from 12:00 to 13:00
Laboratory	5.5	
Prep Room	4	
Office/Staff	4	100% gain from 09:00 to 16:00
Circulation	3	
WC	3	

5.5.3. Equipment Gains

Equipment gains are assigned to all spaces containing equipment, with the applicable gain values and operating schedules defined for each room type. The assumed equipment gains and corresponding profiles are presented in Table 4.

Table 4: Equipment gains for each room type

Room Type	Power density (W/m2)	Profile
MFL	10	100% gain from 09:00 to 12:00 & 13:00 to 16:00 0% gain from 12:00 to 13:00
Laboratory	15	
Office/Staff	12	60% gain from 08:30 to 09:00 90% gain from 12:00 to 13:00 40% gain from 09:00 to 12:00 & 13:00 to 16:30
Prep	20	20% gain from 00:00 to 07:00 & 16:00 to 24:00 100% gain from 09:00 to 12:00 & 13:00 to 16:00 40% gain from 12:00 to 13:00

6. BASELINE RESULTS

The results for the baseline scenario are presented in the following tables. As previously mentioned, since the assessed spaces are naturally ventilated, each space is evaluated against the CIBSE TM52 thermal comfort criteria and the applicable IAQ requirements for naturally ventilated spaces.

Table 5: BB101 baseline results for DSY1 weather scenario

Naturally Ventilated Room Name	TM52 Criteria			IAQ Criteria		TM52 & IAQ Compliant?
	Criterion 1	Criterion 2	Criterion 3	Occupied Peak Average	Occupied Average	
TM52 Max. Value	40	6	4	<1500 PPM	<1200 PPM	
GF GEN LAB II	39	16	5	1942	756	No
GF GEN LAB I	32	13	5	2012	742	No
GF P4 LAB	63	16	5	1942	916	No
GF P3 LAB	48	14	4	1979	876	No
GF C3 LAB	50	15	5	1971	873	No
GF C4 LAB	66	16	5	2008	879	No
GF C1 LAB	50	16	5	2013	760	No
GF C2 LAB	68	17	5	2006	878	No
GF C PREP	41	13	4	1412	663	No
GF P PREP	50	14	4	1412	664	No
GF P2 LAB	73	17	5	2018	930	No
GF P1 LAB	46	17	5	2017	765	No
GF B1 LAB	58	18	5	2013	752	No
GF B2 LAB	88	19	6	2009	879	No
GF B PREP	52	15	5	1411	665	No
GF STAFF ROOM	10	7	2	958	543	Yes
GF MFL 3	47	14	5	2484	1088	No
GF MFL 2	51	14	5	2476	1086	No
GF MFL 1	42	14	5	2503	1094	No
GF MFL OFFICE I	7	6	2	1009	513	Yes
GF SC OFFICE II	6	6	2	1009	516	Yes
GF SC OFFICE I	14	11	3	1014	534	Yes
GF MFL OFFICE II	7	8	2	1005	507	Yes
GF MFL 6	42	14	5	2483	1090	No
GF MFL 5	60	15	5	2460	1083	No
GF MFL 4	57	15	5	2466	1084	No
GF GEN CLASS	60	15	5	2535	1099	No
GF B3 LAB	62	17	5	1976	874	No
GF B4 LAB	178	31	8	2010	872	No
GF MEETING SEMINAR 01	14	7	2	2002	831	No
GF MEETING SEMINAR 02	13	7	2	1098	641	Yes

Table 6: BB101 baseline results for DSY2 weather scenario

Naturally Ventilated Room Name	TM52 Criteria			IAQ Criteria		TM52 & IAQ Compliant?
	Criterion 1	Criterion 2	Criterion 3	Occupied Peak Average	Occupied Average	
TM52 Max. Value	40	6	4	<1500 PPM	<1200 PPM	
GF GEN LAB II	47	28	8	1943	708	No
GF GEN LAB I	48	28	8	2012	706	No
GF P4 LAB	85	28	8	1945	892	No
GF P3 LAB	68	28	8	1982	847	No
GF C3 LAB	70	27	7	1975	849	No
GF C4 LAB	85	28	8	2010	854	No
GF C1 LAB	55	30	8	1998	717	No
GF C2 LAB	86	30	8	2006	853	No
GF C PREP	58	26	7	1411	643	No
GF P PREP	69	29	8	1410	639	No
GF P2 LAB	95	32	8	2016	904	No
GF P1 LAB	57	31	8	2002	706	No
GF B1 LAB	64	32	9	1997	693	No
GF B2 LAB	104	34	9	2008	847	No
GF B PREP	69	29	8	1410	639	No
GF STAFF ROOM	16	18	4	952	533	Yes
GF MFL 3	65	26	7	2472	1064	No
GF MFL 2	68	26	7	2463	1062	No
GF MFL 1	56	25	7	2484	1069	No
GF MFL OFFICE I	15	20	4	1016	493	Yes
GF SC OFFICE II	13	18	4	1020	491	Yes
GF SC OFFICE I	29	27	5	1002	514	No
GF MFL OFFICE II	18	21	5	1009	485	No
GF MFL 6	62	26	7	2473	1066	No
GF MFL 5	77	27	7	2452	1059	No
GF MFL 4	75	27	7	2456	1060	No
GF GEN CLASS	74	26	7	2526	1073	No
GF B3 LAB	78	30	8	1976	845	No
GF B4 LAB	181	47	12	1994	839	No
GF MEETING SEMINAR 01	37	19	4	2031	774	No
GF MEETING SEMINAR 02	33	18	4	1110	621	Yes

Table 7: BB101 baseline results for DSY3 weather scenario

Naturally Ventilated Room Name	TM52 Criteria			IAQ Criteria		TM52 & IAQ Compliant?
	Criterion 1	Criterion 2	Criterion 3	Occupied Peak Average	Occupied Average	
TM52 Max. Value	40	6	4	<1500 PPM	<1200 PPM	
GF GEN LAB II	62	25	7	1949	784	No
GF GEN LAB I	47	22	7	2023	770	No
GF P4 LAB	78	25	7	1947	929	No
GF P3 LAB	66	22	6	1981	893	No
GF C3 LAB	64	24	7	1980	889	No
GF C4 LAB	74	26	7	2016	895	No
GF C1 LAB	51	26	7	2022	782	No
GF C2 LAB	78	26	7	2014	894	No
GF C PREP	56	23	6	1417	672	No
GF P PREP	67	23	6	1417	674	No
GF P2 LAB	85	26	7	2019	944	No
GF P1 LAB	58	26	7	2024	787	No
GF B1 LAB	59	26	7	2022	775	No
GF B2 LAB	87	28	8	2016	895	No
GF B PREP	70	24	7	1416	674	No
GF STAFF ROOM	19	13	3	957	554	Yes
GF MFL 3	63	23	6	2467	1109	No
GF MFL 2	65	24	7	2457	1106	No
GF MFL 1	57	22	6	2475	1114	No
GF MFL OFFICE I	17	17	4	1018	527	Yes
GF SC OFFICE II	13	13	3	1023	530	Yes
GF SC OFFICE I	32	19	4	1017	546	Yes
GF MFL OFFICE II	23	17	4	1008	521	Yes
GF MFL 6	61	24	7	2467	1110	No
GF MFL 5	70	24	7	2452	1103	No
GF MFL 4	69	24	7	2452	1104	No
GF GEN CLASS	70	24	7	2520	1120	No
GF B3 LAB	74	26	7	1982	891	No
GF B4 LAB	155	44	11	2020	889	No
GF MEETING SEMINAR 01	30	13	3	1975	840	No
GF MEETING SEMINAR 02	25	14	3	1096	653	Yes

After analysing the results, it can be observed that natural ventilation without additional mitigation measures is not sufficient to achieve compliance with the CIBSE TM52 and IAQ requirements. Although passive mitigation measures may help reduce the overheating risk, they do not provide a reliable means of improving indoor air quality, and the high CO₂ concentrations observed in certain spaces would remain a concern. Therefore, an alternative ventilation strategy needs to be considered that can effectively reduce the overheating risk while also maintaining the required indoor air quality.

7. LONDON PLAN COOLING HIERARCHY AND PASSIVE DESIGN ASSESSMENT

7.1. Tested Passive Measures

The development has been assessed against the cooling hierarchy in London Plan Policy SI 4. The baseline results in Section 6 show that the proposed building with openable windows alone does not meet all overheating and indoor air quality criteria. Before selecting mechanical ventilation and active cooling, the following feasible measures were tested to reduce solar and internal heat gains and improve passive ventilation.

Measure tested	Model change	Adopted
Reduced solar gain through glazing	Façades, glazing area and/or tested g-values	Yes - solar-control glazing, with a g-value of 0.4. Window area cannot be reduced as daylight levels need to be retained
External shading	Horizontal overhangs, brise-soleil, external roller screens, recessed windows	No - External shading was considered as part of the passive design assessment. A model run incorporating shading devices on the south, east and west façades reduced overheating marginally compared with the proposed design. It did not remove the need for mechanical ventilation to meet the BB101 indoor air quality or overheating criteria. Given its limited additional benefit and reduction in daylight, construction and operational constraint, external shading devices such as shutters or brise-soleil have not been incorporated. Yes - Where the modular façade depth permits windows will be set back as far as possible to aid shading. Yes -The proposed solar-control glazing, with a g-value of 0.4 is retained in the final design.
Roof and façade finish	Tested solar reflectance/finish	Yes - A light-coloured membrane, coating or factory-finished roof panel with a documented solar reflectance and thermal emittance will be installed. Roof will be partially shaded by PV panels which will reduce solar gain.
Internal gains	Lighting/equipment assumptions tested	Yes - measures implemented to reduce internal heat gains are: - Lighting: Specification of efficient LEDs with presence detection and daylight dimming, so lights dim or switch off when they are not needed. - Classroom equipment: Specification of efficient devices and switching off computers, displays and laboratory equipment between uses.

		- Preparation rooms: Put nonessential equipment on shutdown schedules while keeping equipment that must run continuously, such as refrigeration, in operation. - Offices: Enable computer and monitor power management and avoid unnecessary overnight operation.
		Yes - The usable openable area of the windows has been maximised within the applicable safety and operational constraints and is reflected in the overheating model. A clear cross-ventilation path is provided when the internal doors are open. High- and low-level openings are incorporated where feasible to help warm air escape. The locations, effective opening areas and operating assumptions for these openings are shown on elevation drawings and included in the updated BB101 assessment. No - Overnight opening of classroom windows has not been adopted because the temporary school building will be unoccupied and secured during this period. Leaving windows open would require a secure, weather-protected opening and an operating arrangement that can be maintained throughout the building's use. The windows are therefore assumed closed outside their stated operating hours. Overnight heat removal is instead provided through the HVR XC+ night-cooling mode described in Section 7.3, when outdoor conditions permit. The model uses these operating assumptions. No - Automatic window actuators have not been specified. The report's window-opening assumptions will be checked against the proposed manual operation and amended if necessary; the HVR XC+ temperature and CO₂ controls remain part of the design.
Natural ventilation	Opening area, controls and night ventilation tested	

The assessment demonstrates that feasible passive measures have been incorporated to reduce solar and internal heat gains and improve natural ventilation. These include solar-control glazing, a reflective roof finish, efficient lighting and equipment controls, and maximised usable window openings. Additional external shading devices were assessed but have not been adopted because they provided only a marginal reduction in overheating while affecting daylight and the temporary modular design. Recessed windows will provide shading where construction permits.

The passive measures reduce heat gain but do not, on their own, achieve all BB101 overheating and indoor air quality criteria. The proposed hybrid ventilation system therefore provides the remaining ventilation and cooling required. Its night-cooling mode operates when outdoor conditions permit, while classroom windows remain closed overnight for security.

8. UPDATED VENTILATION STRATEGY

8.1. Hybrid Ventilation Strategy

The proposed updated ventilation strategy for Highgate School comprises natural ventilation through the opening windows, together with mechanical ventilation provided by the Monodraught HRV system. As the assessed rooms are served by both natural and mechanical ventilation, they are considered to operate under a hybrid ventilation strategy. Consequently, all assessed spaces are evaluated against both the CIBSE TM52 criteria applicable to naturally ventilated spaces and the PMV index criteria applicable to mechanically ventilated spaces.

8.2. Monodraught HRV XC+ System

The Monodraught HVR XC+ system is a decentralised hybrid ventilation unit that incorporates a heat exchanger together with integrated room heating and cooling coils, allowing it to provide ventilation and thermal conditioning throughout the year. The system is designed to maintain adequate indoor air quality while supporting compliance with the overheating mitigation requirements of BB101 for educational buildings. The HVR XC+ can operate in natural, hybrid, or low-energy mechanical ventilation modes, allowing the system to minimise energy consumption while maintaining suitable indoor environmental conditions.

Building on the features of the Zero model, the XC+ incorporates an aluminium cross-flow heat exchanger and a backward-curved EC exhaust fan, enabling mechanical heat recovery ventilation during the winter period. This additional operating mode allows the system to achieve a low overall energy balance while minimising electrical power consumption. The XC+ also incorporates a heating coil capable of providing the primary heating requirement of the room, using lower water flow temperatures associated with renewable heating technologies such as heat pumps. By integrating ventilation, heat recovery, and heating within a single system, the XC+ reduces the overall energy consumption of the building while maintaining coordinated and efficient system control.

The system incorporates an intelligent, fully automated control strategy combined with a low-energy ventilation system. The operating mode is automatically adjusted depending on the season, internal and external temperatures, and indoor air quality (IAQ). Natural ventilation is used as the primary operating mode, with the internal low-energy fan activated when room temperature or CO₂ concentration increases. The fan operates at variable speeds according to the prevailing room conditions, providing fan-assisted natural ventilation when required.

The system also provides automatic night-time cooling, using natural ventilation through window openings or fan-assisted ventilation where additional airflow is required. During winter operation, the dampers automatically modulate the proportion of recirculated and external air to maintain suitable ventilation temperatures while supporting efficient heat recovery.



Figure 3: Monodraught HVR XC+

Operation Modes

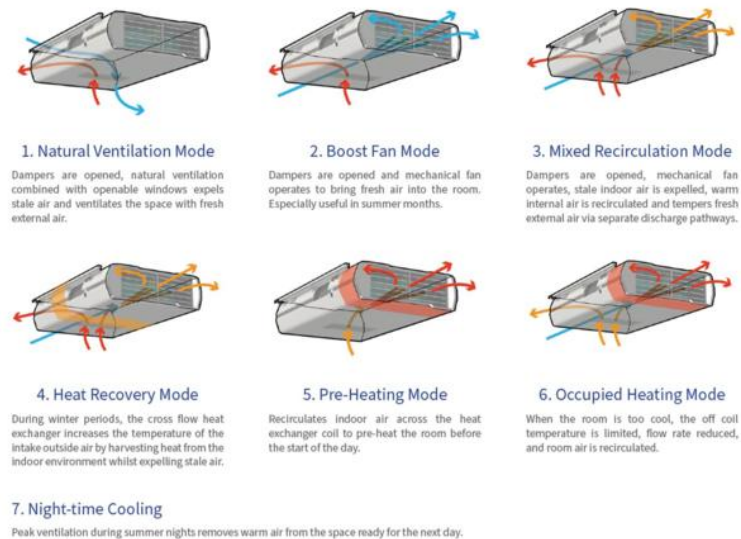


Figure 4: Monodraught HVR XC+ operation modes

8.3. Control sequences of the hybrid ventilation system

To simulate the expected real-life operating conditions as accurately as possible, the following control sequence logic has been implemented in IES VE:

- To maintain thermal comfort, the windows are modelled to start opening when the internal room temperature reaches 21°C and to be fully open at 23°C. The HVR XC+ unit starts opening its louvres at 22.5°C and reaches the fully open position at 24°C. As mechanical cooling is set to activate at 24°C, the windows are fully closed above this temperature. Neither the windows nor the HVR XC+ unit is permitted to open when the external air temperature is higher than the internal room temperature. In addition, natural ventilation is only enabled when the external air temperature is above 15°C.
- To maintain indoor air quality, the windows start opening when the internal CO₂ concentration reaches 900 ppm and are fully open at 1,100 ppm. The HVR XC+ unit is activated when the CO₂ concentration reaches 1,100 ppm. Natural ventilation is only enabled when the external air temperature is above 15°C.

These control sequences are applied during the operating period from 08:00 to 17:00 for the windows, while the HVR XC+ unit operates at occupied capacity from 06:00 to 22:00. This approach allows the model to account for conditions both before and after the scheduled occupancy period. Outside the window operating period, the windows are considered fully closed. During the night-time period, the HVR XC+ unit operates in night-time cooling mode when the external air temperature is lower than the internal room temperature.

The above control strategy is applied during the summer period from May to September. During the remainder of the year, the windows are considered fully closed, while the HVR XC+ unit remains operational throughout the year to maintain the required indoor air quality and thermal comfort.

A graphical representation of the hybrid ventilation sequence between the windows and the HVR XC+ unit is provided in Figure 5.

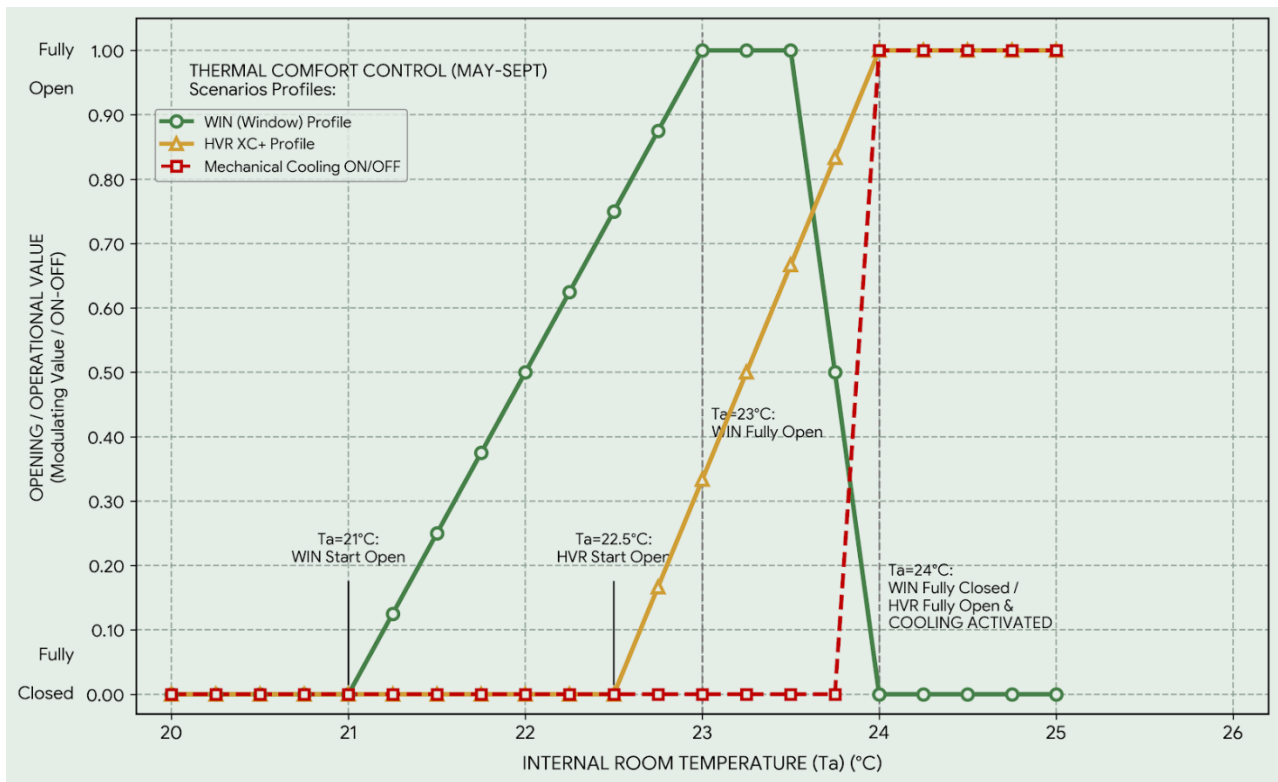


Figure 5: Window, louvre and mechanical cooling modulating value graph

8.4. Determining number of units for each room

Based on the established control sequence and the selected Monodraught HVR XC+ unit, the following number of units has been specified for each space. The number of units has been determined based on the requirement for the building to achieve compliance under all three weather scenarios (DSY1, DSY2, and DSY3), without any individual space failing the assessment. The number of units assigned to each space is presented in Table 8.

Table 8: Number of units assigned to each space

Number of units	Room Name
1xHVR Zero XC+	GF MFL OFFICE I
	GF SC OFFICE I
	GF MFL OFFICE II
2xHRV Zero XC+	GF P3 LAB
	GF C3 LAB
	GF C PREP
	GF P PREP
	GF B PREP
	GF STAFF ROOM
	GF MFL 3
	GF MFL 2
	GF MFL 1
	GF MFL 6
	GF MFL 5
	GF MFL 4
	GF SC OFFICE II
	GF GEN CLASS
3xHRV Zero XC+	GF GEN LAB I
	GF GEN LAB II
	GF P4 LAB
	GF C4 LAB
	GF C1 LAB
	GF C2 LAB
	GF P2 LAB
	GF P1 LAB
	GF B2 LAB
	GF B3 LAB
	GF B4 LAB
4xHRV Zero XC+	GF B1 LAB

9. MITIGATION MEASURE RESULTS

The results of the proposed mitigation measures against both overheating and IAQ criteria for naturally and mechanically ventilated modes are presented in the table below. As the HVR XC+ units have been selected to achieve compliance under all three Design Summer Year scenarios, all assessed rooms pass both the overheating and IAQ requirements.

Further optimisation of the HVR XC+ units could be considered to reduce the number or capacity of units by targeting compliance with DSY1, which is the only mandatory weather scenario for the assessment. This could potentially result in marginally worse performance under the other two weather scenarios, particularly DSY2, which represents the most critical of the three scenarios.

Table 9: Overheating criteria results for updated ventilation strategy DSY1 weather file

Room Name	TM52 Criteria				PMV Comfort Checks		TM52 & PMV Compliant?
	Occupied hours (Natural mode)	Criterion 1	Criterion 2	Criterion 3	Occupied hours (Mechanical mode)	Hours PMV	
TM52 Max. Value		40	6	4		>+0.5	
GF GEN LAB II	290	0	0	0	411	0	Yes
GF GEN LAB I	312	0	0	0	389	0	Yes
GF P4 LAB	151	0	0	0	551	0	Yes
GF P3 LAB	179	0	0	0	522	0	Yes
GF C3 LAB	164	0	0	0	537	0	Yes
GF C4 LAB	163	0	0	0	539	0	Yes
GF C1 LAB	261	0	0	0	441	0	Yes
GF C2 LAB	159	0	0	0	543	0	Yes
GF C PREP	266	0	0	0	542	0	Yes
GF P PREP	268	0	0	0	540	0	Yes
GF P2 LAB	141	0	0	0	561	0	Yes
GF P1 LAB	259	0	0	0	442	0	Yes
GF B1 LAB	263	0	0	0	438	0	Yes
GF B2 LAB	141	0	0	0	561	0	Yes
GF B PREP	242	0	0	0	567	0	Yes
GF STAFF ROOM	486	0	0	0	283	0	Yes
GF MFL 3	129	0	0	0	570	0	Yes
GF MFL 2	128	0	0	0	572	0	Yes
GF MFL 1	135	0	0	0	563	0	Yes
GF MFL OFFICE I	499	0	0	0	266	0	Yes
GF SC OFFICE II	549	0	0	0	218	0	Yes
GF SC OFFICE I	475	0	0	0	288	0	Yes
GF MFL OFFICE II	552	0	0	0	215	0	Yes
GF MFL 6	136	0	0	0	563	0	Yes
GF MFL 5	131	0	0	0	568	0	Yes
GF MFL 4	129	0	0	0	570	0	Yes
GF GEN CLASS	110	0	0	0	590	0	Yes
GF B3 LAB	159	0	0	0	538	0	Yes
GF B4 LAB	147	0	0	0	555	0	Yes
GF MEETING SEMINAR 01	763	0	0	0	0	0	Yes
GF MEETING SEMINAR 02	763	0	0	0	0	0	Yes

Table 10: Overheating criteria results for updated ventilation strategy DSY2 weather file

Room Name	TM52 Criteria				PMV Comfort Checks		TM52 & PMV Compliant?
	Occupied hours (Natural mode)	Criterion 1	Criterion 2	Criterion 3	Occupied hours (Mechanical mode)	Hours PMV	
TM52 Max. Value		40	6	4		>+0.5	
GF GEN LAB II	280	0	0	0	398	0	Yes
GF GEN LAB I	288	0	0	0	391	0	Yes
GF P4 LAB	134	0	0	0	544	0	Yes
GF P3 LAB	158	0	0	0	520	0	Yes
GF C3 LAB	144	0	0	0	534	0	Yes
GF C4 LAB	142	0	0	0	537	0	Yes
GF C1 LAB	234	0	0	0	444	0	Yes
GF C2 LAB	139	0	0	0	540	0	Yes
GF C PREP	243	0	0	0	543	0	Yes
GF P PREP	244	0	0	0	543	0	Yes
GF P2 LAB	127	0	0	0	551	0	Yes
GF P1 LAB	258	0	0	0	420	0	Yes
GF B1 LAB	259	0	0	0	419	0	Yes
GF B2 LAB	129	0	0	0	549	0	Yes
GF B PREP	213	0	0	0	571	0	Yes
GF STAFF ROOM	444	0	0	0	326	0	Yes
GF MFL 3	113	0	0	0	565	0	Yes
GF MFL 2	111	0	0	0	566	0	Yes
GF MFL 1	114	0	0	0	564	0	Yes
GF MFL OFFICE I	492	0	0	0	278	0	Yes
GF SC OFFICE II	536	0	0	0	234	0	Yes
GF SC OFFICE I	442	0	0	0	328	0	Yes
GF MFL OFFICE II	539	0	0	0	231	0	Yes
GF MFL 6	113	0	0	0	565	0	Yes
GF MFL 5	107	0	0	0	570	0	Yes
GF MFL 4	108	0	0	0	570	0	Yes
GF GEN CLASS	88	0	0	0	590	0	Yes
GF B3 LAB	148	0	0	0	531	0	Yes
GF B4 LAB	133	0	0	0	545	0	Yes
GF MEETING SEMINAR 01	770	0	0	0	0	0	Yes
GF MEETING SEMINAR 02	770	0	0	0	0	0	Yes

Table 11: Overheating criteria results for updated ventilation strategy DSY3 weather file

Room Name	TM52 Criteria				PMV Comfort Checks		TM52 & PMV Compliant?
	Occupied hours (Natural mode)	Criterion 1	Criterion 2	Criterion 3	Occupied hours (Mechanical mode)	Hours PMV	
TM52 Max. Value		40	6	4		>+0.5	
GF GEN LAB II	275	0	0	0	418	0	Yes
GF GEN LAB I	305	0	0	0	388	0	Yes
GF P4 LAB	174	0	0	0	519	0	Yes
GF P3 LAB	196	0	0	0	497	0	Yes
GF C3 LAB	187	0	0	0	505	0	Yes
GF C4 LAB	186	0	0	0	507	0	Yes
GF C1 LAB	272	0	0	0	421	0	Yes
GF C2 LAB	181	0	0	0	512	0	Yes
GF C PREP	295	0	0	0	506	0	Yes
GF P PREP	302	0	0	0	501	0	Yes
GF P2 LAB	170	0	0	0	523	0	Yes
GF P1 LAB	271	0	0	0	422	0	Yes
GF B1 LAB	266	0	0	0	427	0	Yes
GF B2 LAB	162	0	0	0	531	0	Yes
GF B PREP	263	0	0	0	538	0	Yes
GF STAFF ROOM	498	0	0	0	273	0	Yes
GF MFL 3	152	0	0	0	539	0	Yes
GF MFL 2	149	0	0	0	542	0	Yes
GF MFL 1	152	0	0	0	537	0	Yes
GF MFL OFFICE I	520	0	0	0	251	0	Yes
GF SC OFFICE II	527	0	0	0	247	0	Yes
GF SC OFFICE I	481	0	0	0	290	0	Yes
GF MFL OFFICE II	545	0	0	0	225	0	Yes
GF MFL 6	154	0	0	0	536	0	Yes
GF MFL 5	149	0	0	0	541	0	Yes
GF MFL 4	147	0	0	0	545	0	Yes
GF GEN CLASS	133	0	0	0	559	0	Yes
GF B3 LAB	179	0	0	0	514	0	Yes
GF B4 LAB	163	0	0	0	530	0	Yes
GF MEETING SEMINAR 01	770	0	0	0	0	0	Yes
GF MEETING SEMINAR 02	770	0	0	0	0	0	Yes

Table 12: IAQ criteria results for updated ventilation strategy DSY1 weather file

Room Name	Natural Mode Criteria			Mechanical Mode Criteria		IAQ Compliant?
	Occupied hours (Natural mode)	Occupied peak average	Occupied average	Occupied hours (Mechanical mode)	Occupied peak average	
TM52 Max. Value		<1500	<1200		<1000	
GF GEN LAB II	291	818	565	411	870	Yes
GF GEN LAB I	313	826	546	389	877	Yes
GF P4 LAB	151	918	726	551	870	Yes
GF P3 LAB	180	871	689	522	874	Yes
GF C3 LAB	165	842	685	537	874	Yes
GF C4 LAB	163	840	683	539	871	Yes
GF C1 LAB	261	724	553	441	879	Yes
GF C2 LAB	159	836	682	543	870	Yes
GF C PREP	277	796	560	542	841	Yes
GF P PREP	279	824	563	540	843	Yes
GF P2 LAB	141	918	724	561	873	Yes
GF P1 LAB	260	819	557	442	882	Yes
GF B1 LAB	264	841	546	438	855	Yes
GF B2 LAB	141	840	682	561	883	Yes
GF B PREP	252	797	558	567	841	Yes
GF STAFF ROOM	536	745	540	283	818	Yes
GF MFL 3	132	940	775	570	902	Yes
GF MFL 2	130	936	776	572	902	Yes
GF MFL 1	139	939	774	563	905	Yes
GF MFL OFFICE I	553	722	494	266	790	Yes
GF SC OFFICE II	601	719	490	218	715	Yes
GF SC OFFICE I	531	722	533	288	741	Yes
GF MFL OFFICE II	604	725	492	215	820	Yes
GF MFL 6	139	943	779	563	902	Yes
GF MFL 5	134	941	778	568	902	Yes
GF MFL 4	132	939	779	570	902	Yes
GF GEN CLASS	112	937	776	590	946	Yes
GF B3 LAB	164	832	681	538	851	Yes
GF B4 LAB	147	847	687	555	881	Yes
GF MEETING SEMINAR 01	819	969	723	0	0	Yes
GF MEETING SEMINAR 02	819	708	596	0	0	Yes

Table 13: IAQ criteria results for updated ventilation strategy DSY2 weather file

Room Name	Natural Mode Criteria			Mechanical Mode Criteria		IAQ Compliant?
	Occupied hours (Natural mode)	Occupied peak average	Occupied average	Occupied hours (Mechanical mode)	Occupied peak average	
TM52 Max. Value		<1500	<1200		<1000	
GF GEN LAB II	298	782	575	398	866	Yes
GF GEN LAB I	305	748	560	391	868	Yes
GF P4 LAB	152	885	734	544	862	Yes
GF P3 LAB	176	869	708	520	867	Yes
GF C3 LAB	162	834	694	534	868	Yes
GF C4 LAB	159	831	696	537	864	Yes
GF C1 LAB	252	724	577	444	868	Yes
GF C2 LAB	156	826	694	540	863	Yes
GF C PREP	269	701	566	543	821	Yes
GF P PREP	269	730	566	543	845	Yes
GF P2 LAB	145	884	730	551	865	Yes
GF P1 LAB	276	765	564	420	870	Yes
GF B1 LAB	277	723	549	419	852	Yes
GF B2 LAB	147	839	685	549	875	Yes
GF B PREP	241	700	563	571	821	Yes
GF STAFF ROOM	486	746	537	326	826	Yes
GF MFL 3	131	931	792	565	886	Yes
GF MFL 2	130	931	792	566	886	Yes
GF MFL 1	132	929	792	564	891	Yes
GF MFL OFFICE I	534	720	482	278	546	Yes
GF SC OFFICE II	578	716	477	234	460	Yes
GF SC OFFICE I	484	717	522	328	526	Yes
GF MFL OFFICE II	581	722	480	231	518	Yes
GF MFL 6	131	932	795	565	891	Yes
GF MFL 5	126	932	793	570	887	Yes
GF MFL 4	126	928	789	570	886	Yes
GF GEN CLASS	106	942	791	590	931	Yes
GF B3 LAB	165	839	683	531	856	Yes
GF B4 LAB	151	851	689	545	864	Yes
GF MEETING SEMINAR 01	812	847	705	0	0	Yes
GF MEETING SEMINAR 02	812	692	590	0	0	Yes

Room Name	Natural Mode Criteria			Mechanical Mode Criteria		IAQ Compliant?
	Occupied hours (Natural mode)	Occupied peak average	Occupied average	Occupied hours (Mechanical mode)	Occupied peak average	
TM52 Max. Value		<1500	<1200		<1000	
GF GEN LAB II	278	845	572	418	872	Yes
GF GEN LAB I	308	785	547	388	881	Yes
GF P4 LAB	177	894	719	519	870	Yes
GF P3 LAB	199	901	697	497	877	Yes
GF C3 LAB	191	864	683	505	883	Yes
GF C4 LAB	189	851	682	507	880	Yes
GF C1 LAB	275	717	557	421	884	Yes
GF C2 LAB	184	846	680	512	880	Yes
GF C PREP	306	797	564	506	840	Yes
GF P PREP	311	811	566	501	827	Yes
GF P2 LAB	173	913	721	523	880	Yes
GF P1 LAB	274	755	561	422	881	Yes
GF B1 LAB	269	752	545	427	853	Yes
GF B2 LAB	165	867	677	531	879	Yes
GF B PREP	274	804	561	538	819	Yes
GF STAFF ROOM	539	744	547	273	840	Yes
GF MFL 3	157	946	778	539	889	Yes
GF MFL 2	154	932	777	542	888	Yes
GF MFL 1	159	932	779	537	893	Yes
GF MFL OFFICE I	561	728	496	251	729	Yes
GF SC OFFICE II	565	720	495	247	685	Yes
GF SC OFFICE I	522	718	535	290	709	Yes
GF MFL OFFICE II	587	727	498	225	570	Yes
GF MFL 6	160	935	779	536	891	Yes
GF MFL 5	155	933	779	541	891	Yes
GF MFL 4	151	931	776	545	888	Yes
GF GEN CLASS	137	929	776	559	932	Yes
GF B3 LAB	182	863	675	514	857	Yes
GF B4 LAB	166	880	681	530	880	Yes
GF MEETING SEMINAR 01	812	912	719	0	0	Yes
GF MEETING SEMINAR 02	812	704	596	0	0	Yes

10. CONCLUSION

The proposed temporary teaching block at Highgate School has been assessed against the BB101 overheating and indoor air quality criteria. Thermal comfort has been assessed using CIBSE TM52 for naturally ventilated operation and the PMV criteria for mechanically ventilated operation. The assessment has also considered the cooling hierarchy in London Plan Policy SI 4.

Thermal modelling was undertaken on the following basis:

- The baseline model uses the proposed building fabric U-values and glazing g-values, together with room-specific occupancy, lighting and equipment gains and operating schedules.
- The building was assessed using all three Design Summer Year weather scenarios: DSY1, DSY2 and DSY3.
- The baseline design, using openable windows alone, did not meet all overheating and indoor air quality criteria.
- Passive measures were assessed before selecting the hybrid ventilation strategy. The proposed design incorporates solar-control glazing with a g-value of 0.4, a light-coloured roof finish, efficient lighting and equipment controls, and the maximum usable window opening area achievable within safety and operational constraints. Cross-ventilation is available when internal doors are open, and high- and low-level openings are provided where feasible.
- External shading options were considered for the south, east and west façades. Separate shading devices were not adopted because their additional benefit was limited relative to their effect on daylight and the constraints of the temporary modular design. Windows will be recessed where the façade construction permits.
- As the passive measures alone did not resolve the remaining overheating and indoor air quality issues, the proposed strategy incorporates Monodraught HVR XC+ units. The building has been assessed against the applicable thermal comfort and indoor air quality criteria in both natural and mechanical operating modes.

The final model indicates that all assessed rooms meet the applicable overheating and indoor air quality criteria under DSY1, DSY2 and DSY3. The passive measures limit heat gains and make use of natural ventilation; the hybrid system addresses the remaining ventilation and thermal comfort requirements. Classroom windows remain closed overnight for security, while the HVR XC+ night-cooling mode operates when outdoor conditions permit.

The number and capacity of HVR XC+ units could be reviewed against DSY1 compliance as a further optimisation exercise. Any reduction would require the overheating and indoor air quality results for the revised design, including its performance under DSY2 and DSY3, to be reported.