Richmond House, London

University of Westminster

Thermal Modelling Analysis

Preliminary Report

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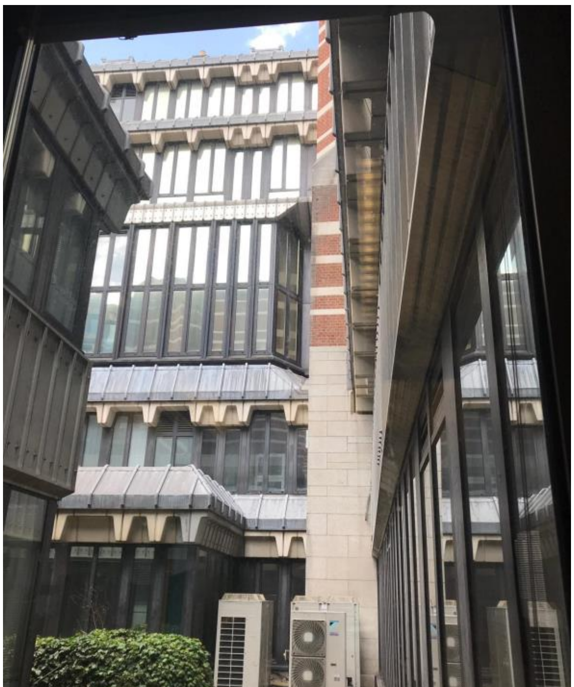
11 May 2020



EXECUTIVE SUMMARY

The re-use of existing office buildings is a vital strategy in order to meet the government's carbon targets by 2050 (*The Climate Change Act 2008 - 2050 Target Amendment*). In an age of growing climate crisis, Richmond House can lead the way.

This new study by the University of Westminster shows how Richmond House can be refurbished to meet the challenges of global warming and reduce operational energy use. By employing natural ventilation, the need for mechanical cooling can be removed, including that of obtrusive air conditioning ducts within the constraint of the existing ceiling heights.

The existing floor-to-ceiling height within Richmond House meets current BCO guidelines for refurbished office space (British Council for Offices, 2014). Thermal modelling analysis shows how a naturally ventilated solution can be developed within the existing floor to ceiling heights **to virtually eliminate all potential overheating, and without recourse to energy hungry air conditioning.** This demonstrates how the existing building can be easily and cost effectively adapted to reduce operational energy costs and create a state of the art, naturally ventilated working environment.

The study demonstrates that there are significant opportunities for creating a state of the art naturally ventilated refurbished building. These include:

- **Increasing ventilation by adding louvers to all windows (facilitating night-time ventilation) and increasing openable area to 30%** with no AC (See Case 3A). Additional natural convective cooling could be introduced by creating more openable window area such as the installation of new ventilation louvre panels which could be incorporated into the existing glazing pattern, for instance, opaque, openable louvres could be installed on top of casement windows. The advantage of this solution is that it will keep in character with the original building. However, in order to maintain good, natural lighting, alternating opaque and transparent sections of louvred panels could be desirable, depending on orientation. The advantage of this solution is that the work could be done externally and in a phased (floor by floor) manner during occupation, minimising disruption and reducing costs. **Overheating frequencies can be reduced below 3% and carbon savings of 12kgCo2e/m2.yr would be achieved**. Over the total floor area, this would yield a total carbon saving of approximately 180 tonnes/yr. **Over just one year this saving would equate to about 180 return flights to New York or 360 return flights to Europe.**

● **Increasing ventilation (as above) and adding stack ventilation (including night-time ventilation and standard open fanlight area above doors)** with no AC (See Case 4A). As well as introducing openable perimeter vents, the existing stair towers could be used to increase air movement to carry warm, stale air out of the building at high level and introduce cool, fresh air from perimeter vents. This would be achieved with the provision of openable panel/s on the top or the sides of the main door to the staircase and an opening at the top of the staircase. The potential limitation due to fire hazards related to the opening between offices and staircase could be counteracted with the employment of fire dumpers which automatically shut when smoke or fire is detected. This option would reduce risks of overheating by 96.7% and save 12kgCO2e/m2.yr, when compared to the base-case scenario (case 1A), and if optimised could provide further cooling in case of extreme hot conditions.

Summary Table of Results

SCENARIO	WINDOWS		AC	LOUVERS	STACK EFFECT	OVERHEATING FREQUENCY (SUMMER)	ANNUAL COOLING LOADS (SUMMER) KWh/m2	CO2 SAVINGS kgCO2e/ m2
1A	existing (only half of windows are openable)	closed	off	-	-	70.1%	-	-
1B		closed	on	-	-	0.0%	47.0	-
1C		open	off	-	-	19.4%	-	-
2A	all windows are openable	open	off	-	-	5.4%	-	-
3A	all windows are openable with louvers on top	open	off	open	-	2.6%	-	12.0
4A	all windows openable, louvers, stack effect	open	off	open	on	2.3%	-	12.0

*Current situation represented by scenario 1B.

THERMAL MODELLING ANALYSIS

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1. INTRODUCTION

The Architecture and Environmental Design research team at the University of Westminster was asked to conduct a feasibility study for the natural ventilation summer strategy for a typical representative office at Richmond House, Whitehall, London. The study was aimed at identifying whether the existing design can provide acceptable comfort conditions in summer through the means of a natural ventilation. The comparative analysis between various scenarios for retrofit of the existing building was undertaken using computational dynamic thermal modelling. It provided a detailed analysis of the frequency of overheating during occupied times and the cooling energy demand of representative offices in the building, for the tested scenarios.

2. OBJECTIVES

The objectives of the study were:

- To assess the feasibility of natural ventilation to provide thermal comfort conditions and reduced cooling energy demand for a representative office space.
- To assess which retrofit strategies would improve thermal comfort, keeping cooling demand at a minimum.

3. METHODOLOGY

The method employed for the feasibility study was based on a fully dynamic thermal modelling and simulation calculation performed with the software TAS Building Designer (Environmental Design Solutions Ltd, 2019). TAS is a suitable software for modelling of natural ventilation, cooling loads calculations and thermal comfort assessments as certified by the BPM[1] checklist (CIBSE, 2015). A full three-dimensional thermal model was created in TAS to represent the building as per the architect's drawings and the building envelope and building services information obtained from SAVE Britain's Heritage. The frequency of overheating and the annual cooling energy demand of a representative open plan office area of the building was calculated over a full summer (1st May to 30th September). The study was based on a comparative analysis between tested scenarios and their relative performance expressed in % of time when the Operative Temperature is above 26°C.

1 CIBSE AM11:2015 Building Performance Modelling.

4. ASSUMPTIONS

4.1. Building Geometry and Zoning

The 3D model (figs. 3, 4) of the existing building was based on the drawing by *abel architects & designers*, dated March 2007 (fig. 1), and measurements taken on site. The analysis was based on a typical office on the fourth floor in the North East corner of the building. The modelled area was subdivided in 2 zones as shown below, where 1 (red) is the office space and 2 (orange) is the kitchen (fig. 2).

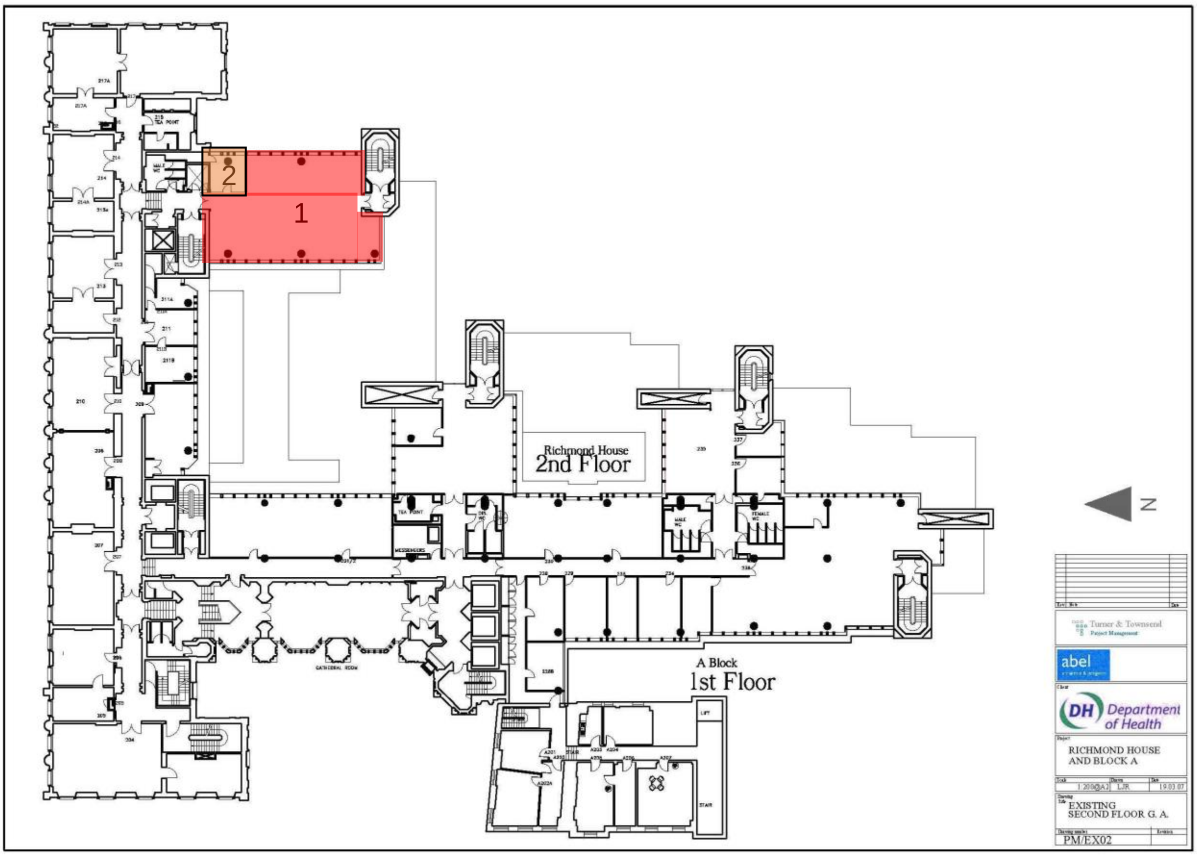

Fig. 1 – Floor Plan of Second Floor with study area highlighted in red

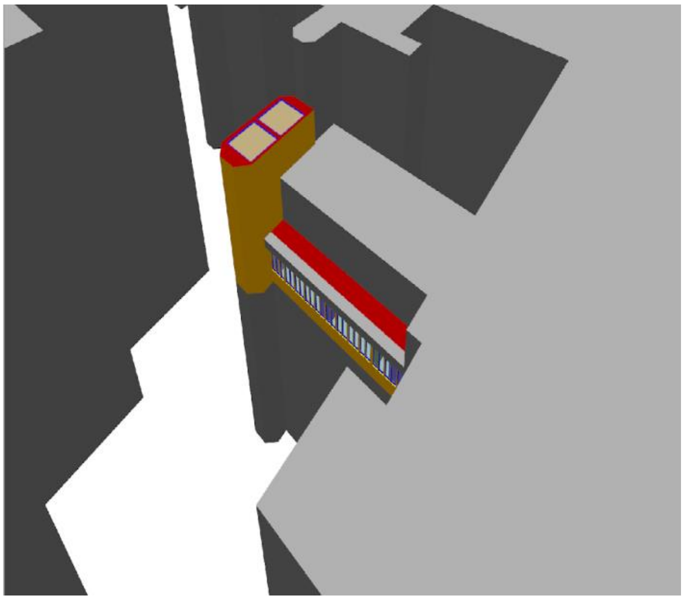

Fig. 2 – 3D view from North-East

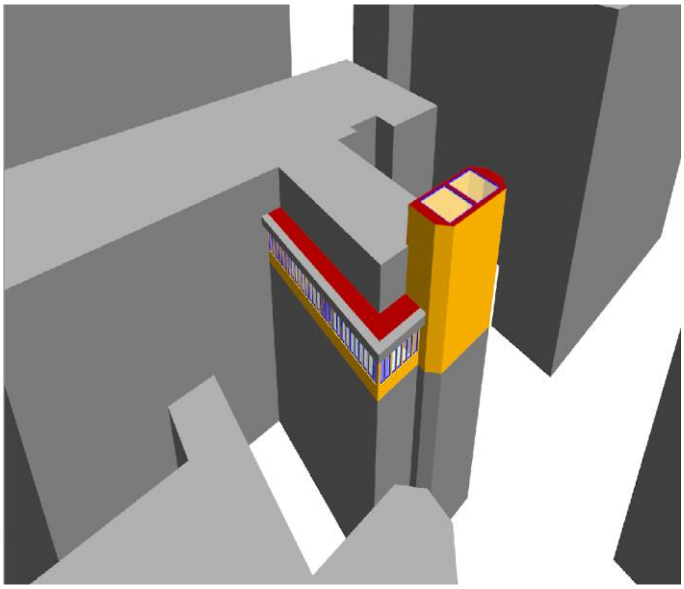

Fig. 3 – 3D view from South-West

4.2. Weather Data and comfort criteria

The weather file used for the simulation was sourced from the weather database software, Meteonorm v.7.2.4. (Meteotest AG, 2018). Specifically, the weather file used was London(1991-2010).epw. The file is representative of the typical weather in London. The statistical data for this file is detailed in the table below.

Table 1 – Weather data Statistics for London (1991-2010).epw

Variable	Units	Min.	Day of Min	Mean	Max.	Day of Max
Global solar	W/m^2	0.00	1	111	931	203
Diffuse solar	W/m^2	0.00	1	65	434	170
Cloud Cover	okta	0.00	4	5.7	8	1
Air Temp.	C	**-1.60**	12	12.36	**28.9**	203
Wind Speed	m/s	0.00	93	3.60	14.90	28
RH	%	29.00	115	70	100.00	12

The comfort criteria were derived from the Adaptive Comfort criteria EN15251 for naturally ventilated buildings (class II buildings) (European Standards, 2012). The calculation for London (fig. 5) indicates a variable upper comfort threshold averaging to 27.45°C between the months of May to Sep. However, in order to follow a conservative approach and reflect the lower temperature expectations of mixed mode buildings a lower upper comfort threshold of 26°C was chosen and the frequency of operative temperatures plotted against this stricter value.

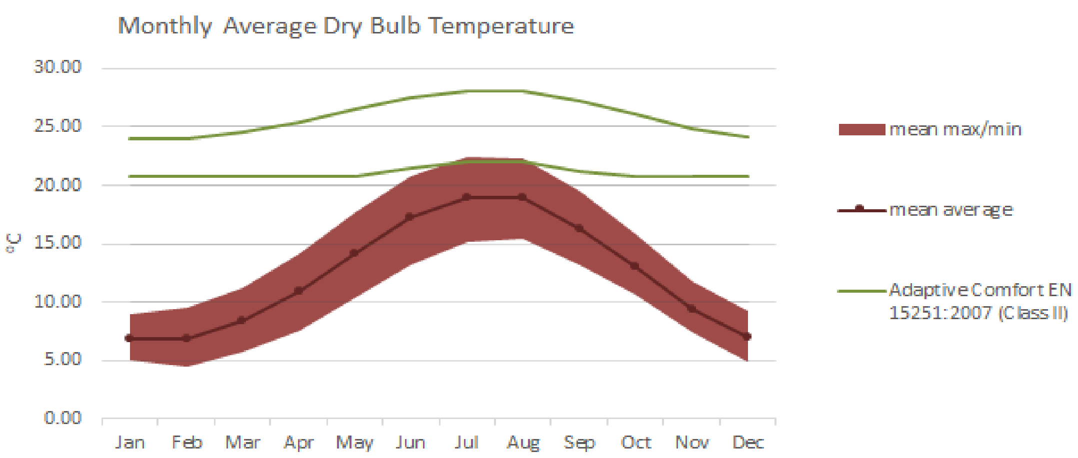

Fig. 4 – Weather profile for London (Meteonorm) and EN15251 comfort band

4.3. Building Elements

Information on the u-values of all building elements, such as windows, roof, walls and slabs, were derived from the building regulations established in 1985 (Department of Energy & Climate Change, 2014) (see Appendix A) which were most likely to be followed at the time of design in the 1990s. These were input into the dynamic thermal modelling software (TAS) as shown in Table 2 below. In addition to the current configuration of the building, assumptions were made for an improved scenario where the windows are upgraded to a higher specification.

Table 2 - Schedule of Building Elements

Element	U-value Current Building (W/m²K)	U-value Improved Building (W/m²K)
Roof	0.31	0.31
Ceiling	1.03	1.03
Floor	1.03	1.03
Internal Partitions	2.02	2.02
External Walls	0.60	0.60
Windows	2.57	1.3

4.4. Internal Conditions and Gains

A breakdown of the internal gains and design conditions is detailed in the table below. The occupancy time for all zones is assumed to be 8-18 during the week in Summer. The cooling demand calculations were performed including fresh air loads of 10l/s/p.

Table 3 - Schedule of Internal Conditions and Gains

Zone	Area (m²)	No. People	Occup. time	Infiltration (ach)	Equipm. Gains (W/m²)	Occupancy Gains (W/m²)	Lighting Gains (W/m²)
1. Work area	143.6	23	8-18	0.5	15	11.2	12
2. Kitchen	11.7	3	8-18	0.5	19	19	10

4.5. Occupancy Profile

The daily pattern of occupancy has been assumed to be constant throughout the day from 8am to 6pm from Monday to Friday (fig. 6). The number of occupants in the office area is 23.

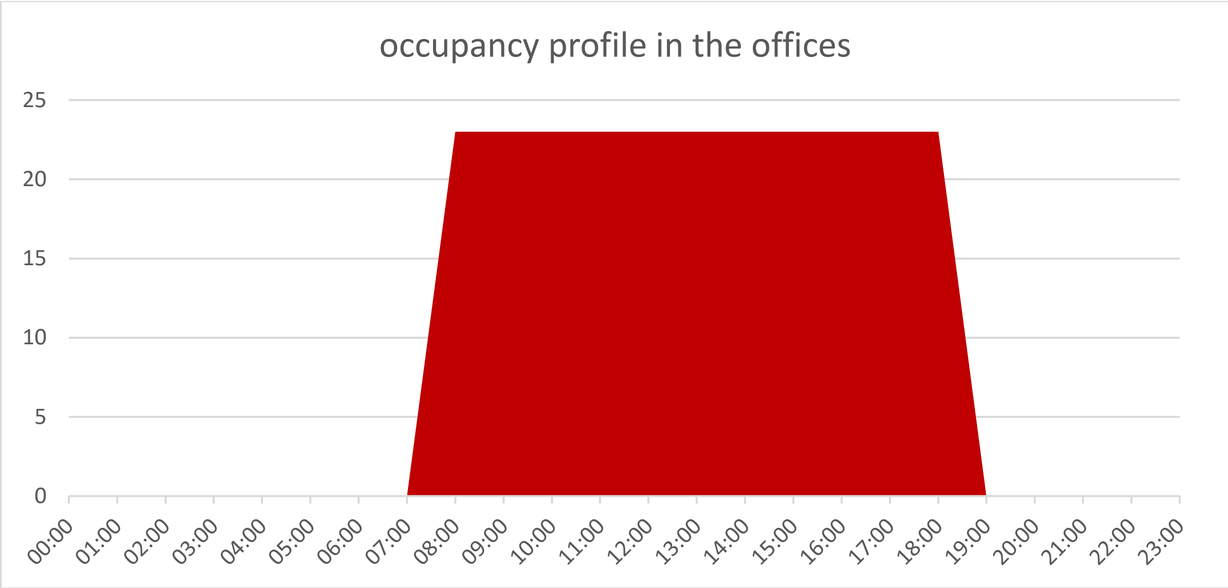

Fig. 5 – Occupancy Profile

4.6. Building Services Strategy

The building has semi-dispersed service cores and raised floors, which appear to be at least 100mm high. All zones are naturally ventilated; however, HVAC devices were installed in between the coffered ceiling panels (fig. 7). Heating is concealed behind ash veneered panels beneath the windows. High quality Schueco aluminium double-glazed windows are manually operated and internal louvre blinds provide solar shading. Given the highly massive interior which benefits from the exposed thermal mass of the coffered ceiling, risks of overheating are manageable if larger opening areas are provided and additional high-level louvers are installed.

Fig. 6 – Cooling units installed between coffered ceiling panels

5. RESULTS

Tested Scenarios

The following scenarios were tested during warmer months (1st May to 30th September; fig. 8):

1: Existing windows (higher Uv and Gv, only half windows are openable)

1a) All windows closed // no AC

1b) All windows closed // AC during occupied hours

1c) Natural ventilated, windows open 20% during occupied hours

2: New windows (lower Uv and Gv, all windows are openable)

2a) Natural ventilated, windows open 30% during occupied hours

3: New windows + Louvers (lower Uv and Gv, all windows are openable, louvers on top)

3a) Natural ventilated, windows open 30% during occupied hours, louvers open 60% (including night-time and weekend ventilation)

4: New windows + Louvers + Stack Effect

4a) Natural ventilated, windows open 30% during occupied hours, louvers open 60%, stack ventilation open 75% (including night-time ventilation)

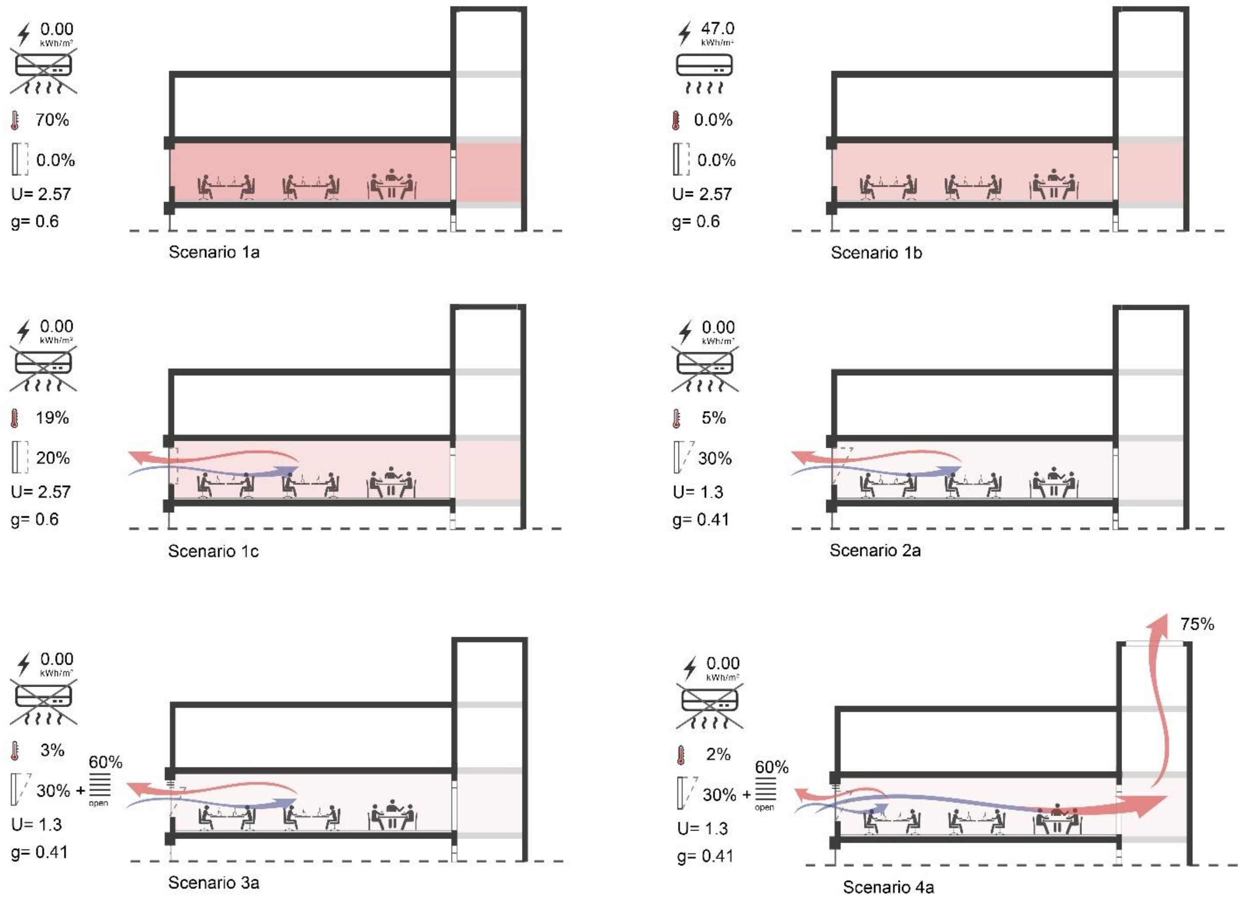

Fig. 7 – Scenarios tested

Peak Cooling Load Calculation

The results for the cooling calculations are summarised in Appendix B. The worst-case scenario was considered for the cooling calculation which was performed with all the windows closed. In this case the total peak cooling load for the work area is 13.8 kW and occur on day 204 when the ambient resultant temperature is 23.88°C.

Cooling Energy Demand and Overheating Frequencies

The annual cooling energy demand for the existing work area conditions in the office is 47 kWh/m^2 (considering all windows closed). This figure drops to 4 KWh/m^2 and no time of overheating when improvements are made in both, the natural ventilation strategy and the envelope specifications (fig.

8). Overheating frequencies for resultant temperatures above 26C, also drop from 70.1% to 2.3% in the best-case scenario.

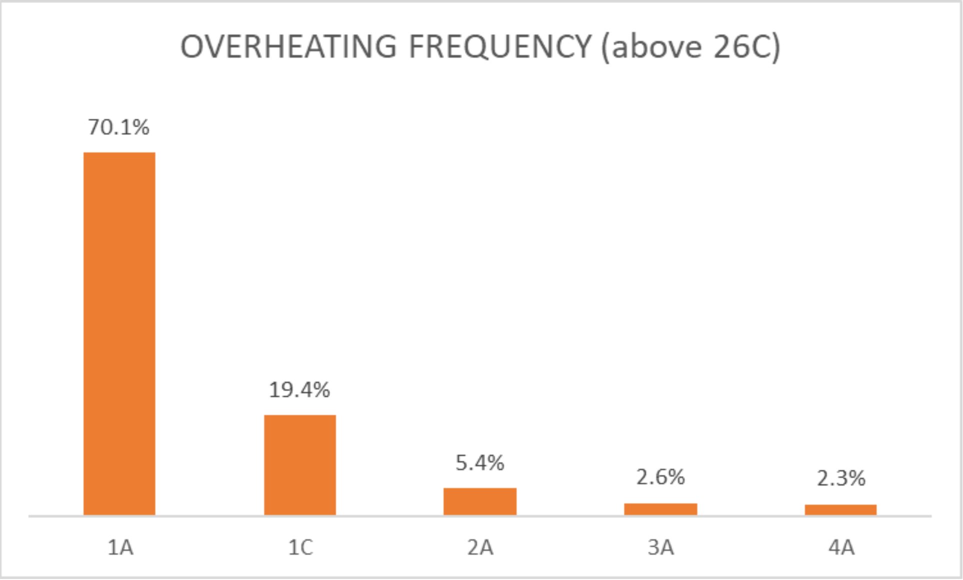

Fig. 8 – Frequencies of overheating for naturally ventilated options.

6. CONCLUSIONS

As shown in the appended table (Appendix B), the scenarios tested indicate that time and cost-effective (refurbishment) strategies, such as enhancing window performance (to increase opening area, improve thermal and solar performance and implement automated vents to allow for night-time ventilation during weekdays and weekends), can significantly improve comfort conditions in Richmond House.

If the existing perimeter windows were replaced by double-glazing with maximum U-value of 1.3 W/m^2K, Solar Factor (g-value) of 41% and Visual Light Transmittance (VLT) of 69%, and openable area of 30%, the frequency of overheating would decrease by 64.6% (from 70.1% to 5.4%) of occupied hours (comparison between scenarios of 1A and 2A).

Besides the improvement of the glazing and windows, If the ventilation strategy considers the addition of louvres at the top of the windows, that open 60% during all weekdays (including night-time), the frequency of overheating would decrease by an additional 2.8% (from 5.4% to 2.6% - comparison between natural ventilated strategies of 2A and 3A).

If the ventilation strategy considers automatically openable windows at the top of the staircase tower to take advantage of the stack effect, the frequency of overheating would decrease by further 0.3% (scenario 4A).

In the scenarios mentioned above (1C, 2A, 3A and 4A) the cooling loads would be null as the strategies are purely based on natural ventilation. This would lead to carbon emission savings of 12kgCO2e/m2 in comparison to the current base case (scenario 1B).

If a fully naturally ventilated option is chosen (e.g. scenario 2B, 3B or 4B), the related carbon emissions savings will be up to 12KgCO_2e/m^2.yr, which, if applied to the entire floor area of Richmond House (15,000m^2), would yield a total carbon saving of approximately 180 tonnes/yr. Over just one year this saving would equate to about 180 return flights to New York or 360 return flights to Europe. However, this saving calculation is based purely on cooling energy demand and not consumption which could be estimated as 10% higher than current demand due to the addition of auxiliary power, pumps and fans.

This study suggests that Richmond House as a Grade II* listed building can significantly improve its performance with minimal cost-effective strategies which are sensitive to its historical heritage and reduce the building's carbon footprint. The main proposed alteration to the current appearance would consist in the introduction of an additional louvered section on the windows which is already present on the current south and west façades, as seen in figure 10 below.

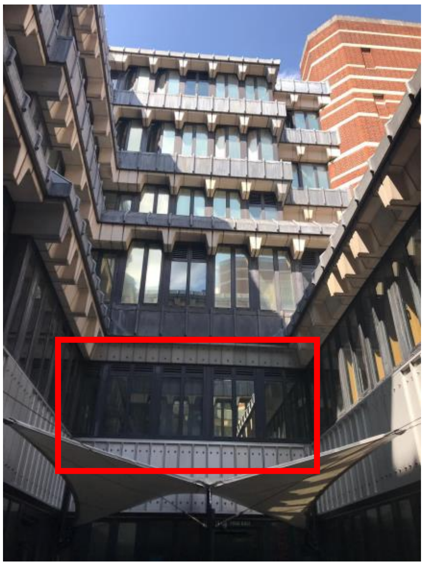

Fig. 10 – Existing windows and louvres

7. LIMITATIONS

This work represents a preliminary study with simplified assumptions and simulations which could potentially lead to optimistic results. Some of those simplifications are, for example, in the thermal zoning of the modelled area, where one single zone has been used to represent the whole of one typical open plan office. Another simplification has been to base the assumptions for the building fabric's thermal properties on the U-values and characteristics of typical construction as published in the Building Regulations at the time of design and construction of the building (1985).

However, care has been taken to assume more conservative upper comfort limits than those calculated according to EN15251 adaptive comfort standard, in order to offset these potential limitations and apply a more rigorous comfort evaluation benchmark. Due to time and resources constraints, this work performed an overheating analysis for Resultant Temperatures above 26°C during the occupied time. Frequencies of overheating below 3% were considered acceptable. However, it is recommended that a more comprehensive thermal comfort protocol is undertaken as part of a detailed analysis, such as that presented in the CIBSE TM52 and considers additional overheating due to climate change scenarios, which was not tested in this preliminary study.

8. ACKNOWLEDGEMENTS

The authors of this report would like to acknowledge the School of Architecture and Cities, University of Westminster, London for providing the necessary resources and support enabling this study. Also, the contribution of Mr Kartikeya Rajput, Principal Environmental Consultant at chapmanbdsp, as peer reviewer of this report is gratefully acknowledged.

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APPENDICES

Appendix A – Summary of Building Regulations (Annex E, 2014, Department of Energy & Climate Change)

Annex E: Summary of Building Regulations

Building Regulations Part L is an energy performance based requirement. It does not specify a particular type of construction or insulation material but minimum performance standards. Given that most homes in England built in particular years are similar constructions it is possible to determine the likely way these standards would be met in a so-called "notional" house. These are set out in this Annex.

Table 1.1: Summary of Domestic Building Regulations Part L

	1985	1990	1995	2002	2006	2010	2013
Roof u-value[1] (W/m^2K)	0.35	0.25	0.20	0.16	0.14	0.13	0.13
Loft insulation	100mm	140mm	160mm	250mm	270mm	300mm	300mm
Wall u-value (W/m^2K)	0.60	0.45	0.35	0.35	0.22	0.22	0.18
Boiler standards[2]				D rated (78% eff.)	B rated (86% eff.)	A rated (89.5% eff.)	89.5% eff.
Heating controls		Timer & thermostat	Timer & thermostat	Zone cont.	Zone cont.	Zone cont.	Zone cont. and weather compensation

[1] A u-value is a measure of heat loss in a building element such as a wall, floor or roof. A lower u-value indicates better thermal performance.
[2] Condensing boilers require water to be drained outside the home. If this is not practical a lower efficiency boiler can be used.

Appendix B – Conditions and results of the tested scenarios for Richmond House

SCENARIO	WINDOWS						AC		LOUVERS		STACK EFFECT		OVERHEATING FREQUENCY (SUMMER)	ANNUAL COOLING LOADS (SUMMER)
	condition	U value	G value	openable fraction	function (Resultant T) begins to open	function (Resultant T) fully open	condition	setpoint (DBT)	openable fraction	schedule	openable fraction	schedule		
1A				-	-	-	off	-	-	-	-	-	70.1%	-
1B	existing (only half of windows are openable)	2.57	0.6	-	-	-	on	20 °C	-	-	-	-	0.0%	47 KWh/m2
1C				20%	21°C	23 °C	off	-	-	-	-	-	19.4%	-
									-	-	-	-		
2A	all windows are openable	1.3	0.41	30%	21°C	23 °C	off	-	-	-	-	-	5.4%	-
									-	-	-	-		
3A	all windows are openable with louvers on top	1.3	0.41	30%	21°C	23 °C	off	-	60%	24hrs	-	-	2.6%	-
											-	-		
4A	all windows openable, louvers, stack effect	1.3	0.41	30%	21°C	23 °C	off	-	60%	24hrs	75%	24hrs	2.3%	-