ENERGY PERFORMANCE & THERMAL COMFORT IN OFFICE BUILDINGS IN RUSSIA

Danny Tran[1], Arman Hashemi[1*], Alex Scott-Whitby[1], Guy Eames[2], Svetlana Alekseyevna Zabelina[3], Kirill Borisovich Zubkov[3], Narguess Khatami[4]

[1] University of East London, School of Architecture, Commuting and Engineering, London, UK
[2] Planet 2030 Ltd., Peterborough, UK
[3] MASI University, Moscow, Russia
[4] Mott McDonald, London, UK
[*] Correspondence: a.hashemi@uel.ac.uk

ABSTRACT

The global aim of the building sustainability is to reduce carbon emissions and achieve zero emission buildings. Building Research Establishment Energy Assessment Methods (BREEAM) are effective tools to assess, improve and provide energy performance certificates for new and existing buildings. This paper assesses energy performance and thermal comfort in a BREEAM certified case study building in Russia, comparatively analysing results through changing the building fabric parameters. The case study is the top floor of an office building in Moscow, where internal conditions, and various parameters were accounted into the simulations in IES (VE). By testing the combinations of each parameter, scenarios with improved energy performance and thermal comfort were found. The results suggest the ideal configuration of parameters for Russia's harsh climate would be to use most optimal U-values and triple paned glazing, implementing a night purging strategy and 1.5m overhang louvres as the solar shading strategies to ensure the building remains thermally comfortable and avoid overheating during summer. It is recommended to reduce excessive glazing to mitigate the impact of heat loss during winter while strengthening the airtightness of the building, though the annual ranges suggest that it may not be enough against Russia's climate throughout the year; particularly in winter, PMV ranging from -2.17 in January to 0.81 in July representing a thermally uncomfortable situation both in summer and winter.

Keywords: BREEAM, Retrofit, Commercial Buildings, Energy Performance, Thermal Comfort.

INTRODUCTION

The last decades have seen rapid development in the field of building sustainability, where there is a global collaboration to improve energy efficiency and mitigate contribution to climate change. One such example is Russia, as buildings use more energy in order to stay operational against its climate, contributing to the intensive energy use, which is the 4th largest energy consuming country in 2020, consuming 28.31 Exajoules (N.Sönnichsen, 2021).

Russia's first regional code was developed in 1994, and starting 2000s, a new set of regulations was made to provide 'a 40% energy reduction for heating' (Y. Matrosov et al, 2007), where building envelope had to improve their performance by 2.5-3 times to do so. This in order resulted in building design to implement better energy efficient materials, and HVAC strategies across the sector to meet energy passport and audit requirements. Russia's construction industry faced many challenges, as a study by S. Anu et al (2015) states the percentage of unfinished construction annually is high, from 2005 to 2011, 10-16 non-residential buildings were completed each year, due to high construction costs and insufficient investments causing in critical delays, on top of the ongoing recession. Demand in the sector rises to meet the growth, increasing energy intensity, despite the target decrease of 56% by 2030.

Matrosov (2007) and Anu (2015) presents a common theme in Russia's ambitious goals, both instances pointing out the large reduction goal, from 40% at the start of the 2000s and to 56% for 2030. However, both studies state that improving code and standards and improving material efficiency, are the main method to achieve this. Though not incorrect, it could suggest a performance gap between the energy target and methods used to improve the building efficiency as target reduction remains high.

In recent years, organisations such as the Building Research Establishment (BRE) and Russian Green Building Council (RuGBC) are working collaboratively to promote green standards in Russian building. Translating and localising schemes from BREEAM including BREEAM international, new construction and in use, to be implemented in Russian regulation, with 60 BREEAM certified buildings as of 2018. Also working with local universities and aims to implement the practice into education, allowing graduates to attain accredited recognition (Telichenko et al, 2018), BRE acts as the overseer while RuGBC assists in the localisation process, but also in codes and regulations.

A recent comparative analysis discusses international green building certification in Russia, comparing different systems such as BREEAM, LEED, STO NOSTROY and others, the author asserts their view in the same vein as the aforementioned theme, stating that 'many requirements for Russian designers are inappropriate or often too high to be implemented' (A. Shvets, 2021). Giving an example of how some systems exclude the use of a few structural materials, that's prevalent in Russian works, further showing the complications of integrating international standards into Russia's code compliance. In terms of thermal comfort, it is well known that the climate in Russia continues to be an obstacle in green building development, within winter, the whole of Russia experiences high cold stress and often even reaching extreme cold stress. While in summer, mid-southern Russia reaching high heat stress (Varentsov M., 2020). This trend is reflected in thermal simulations of buildings in Russia's climate, as research which revolved around the correlation between energy efficiency and ventilation carried out by D. Baranova et al (2017), modelled a single residential unit comparing the impact of a 'never open' and 'always open' ventilation scenario, Both results show a trend in operative temperatures of two separate areas in the unit, with 'never open' using a natural ventilation system while 'always open' adds mechanic mechanical cooling to combat the overheating, which may be caused by trapped internal heat and solar gain with no extraction from mechanical or natural ventilation. These results imply that during summer, 'never open' exceeds 25 C on a monthly average while 'always open' remains under, while December, both temperatures could reach below 20 or 18 C. Though this is in the context of a residential unit, an assumption could be made that the climate will affect commercial buildings in a similar way. The climate, and operative temperature are both important aspects to consider when designing for thermal comfort, which is defined as 'the state of mind that expresses satisfaction with the surrounding environment' according to the Chartered Institute of Building Service Engineers (CIBSE), (Dabner J. et al, 2017). Thermal comfort is normally measured through Predicted Mean Votes (PMV), an index that aims to estimate the average value of votes for a group of users on a thermal sensation scale (Guenther S., 2021). Where the scale has 7 increments, going from cold to hot, these increments are assigned a score from -3 to +3, as seen in table 1, showing the metrics of the thermal sensation from ASHRAE (American society of heating, refrigerating and air conditioning engineers).

Table 1: PMV Thermal Comfort Scale;
Source: (Dabner J. et al, 2017)

-3	-2	-1	0	+1	+2	+3
Cold	Cool	Slightly Cool	Neutral	Slightly Warm	Warm	Hot

Previous research on how building parameters such as shading or glazing impact indoor thermal comfort has established that shading devices can be used in cold climates to improve thermal conditions, yet to a varying degree. This is seen in a two-part study performed on a case study building in Montreal, the first performs an experimental simulation analysis, using roller shades and venetian blinds (at different angles) in winter conditions, then comparing the results, where both data sets are similar in values and patterns. The findings show roller shades would work best on clear conditions, while venetian blinds are only efficient at 45 degrees. Where part two, combines the first part with the thermal transient model, to investigate impacts of varying external conditions, glazing, shading properties against thermal comfort and heating demands. With the outcoming data suggesting certain glazing elements and properties, there will be 'a trade-off between energy, thermal comfort and lighting needs.' (A. Tzempelikos, 2010) where for one trait to be more efficient, another trait may become compromised. This study may relate to the current project, Montreal may be similar in climate and temperature with Moscow, as seen in figure 1, graphs from the National Oceanic & Atmospheric Administration shows that the only average difference is around 2-3 degrees. The premise may also relate as both revolves around investigating how different building elements affects thermal comfort and heating demands with alternative methods.

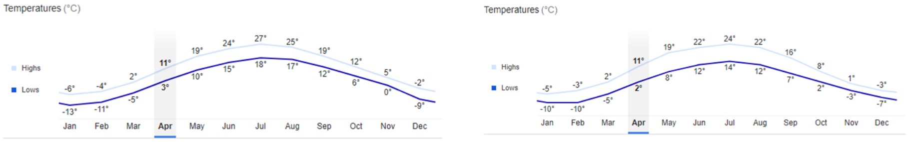


Figure 1: Average high & Low temperature in Montreal, Q.C., Canada (Left) & Moscow, Russia (Right)
Source: NOAA (2022)

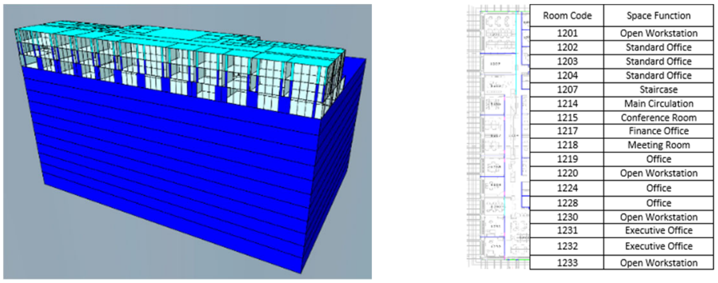
To date, there's little quantitative analysis on Russian commercial building energy performances, though past studies has been executed on residential properties and of office buildings in similar climate, conveying a deficiency of research on Russian office building performances. The research aims to contribute to the body of knowledge by assessing energy performance and thermal comfort, by developing on how improvements through building parameters such as fabric U-value, internal heat gains, schedules and solar shading may affect it. This may be achieved by parametrically comparing combinations of parameters, using a case study floor in Moscow and use an energy modelling software to run simulations and generate data on energy performance and thermal comfort for each. Allowing an assessment and analysis on how energy efficient the case study to be made. The findings should be able to draw conclusions as to how Russian office building's energy efficiency can be better optimised.

METHODOLOGY

Case Study

The research uses the top floor of a Moscow office building for modelling and simulations, which is around 12 storeys high. The building consists of a concrete structure, along with a curtain wall façade and has already been certified by BREEAM, with a rough score for new construction at 40%, and for BREEAM in use part 1 & part 2 both scoring around 57%, though factors included scored high, such as 72% in Health and wellbeing as well as 88% in transport.

In order for the simulation to be accurate, the floor plan of the 12th floor as well as the floor below was modelled in detail, while the rest of the building is only the envelope. Ensuring that the simulation is replicating the same elevation and conditions as reality, for example, the total heat gain and glazing from the floor below may affect the 12th floor, while elevation is important as it factors into the climate condition. The geometry of the model used for the simulation can be seen in figure 2, with the 11th and 12th floor shown in more detail, the building envelope measures to 72m x 48m though the 12th floor perimeter spans around 72m x 18m. The floor plan in figure 6 further shows the different types of areas on the 12th level, most occupied spaces include executive offices, conference rooms and open workstations.



Room Code	Space Function
1201	Open Workstation
1202	Standard Office
1203	Standard Office
1204	Standard Office
1207	Staircase
1214	Main Circulation
1215	Conference Room
1217	Finance Office
1218	Meeting Room
1219	Office
1220	Open Workstation
1224	Office
1228	Office
1230	Open Workstation
1231	Executive Office
1232	Executive Office
1233	Open Workstation

Figure 2: Simulation model and Room schedule

Parameters

The research compares the case study performance under 3 sets of U-Values and under 3 shading scenarios, while comparing results with and without night cooling, alongside other static parameters that may affect simulations, where the findings produce an optimal configuration could be found. From the paper authored by Matrosov (2007), a range of thermal resistance standards can be seen in Europe, where Russia's values can then be inversed to show the U-Value range as shown in table 2:

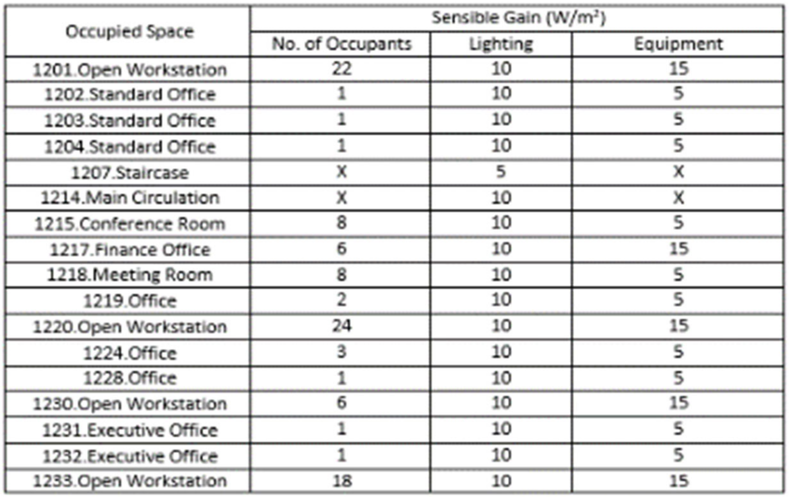
Table 2: U-Value Standards (W/m^2K)

Building Fabric	Poor	Medium	Optimised
Roof	0.340	0.230	0.120
Wall	0.530	0.355	0.180
Intermediate Floor	1.100		
Window	3.800	1.250	1.250

The building operates from, 9am-5pm, staff entering as early as 8pm, and leaving 6pm at the latest through the weekdays. During the occupancy of the building, several equipment, employees, and lighting create internal heat gains, which contributes to the resulting data. Using the number of occupants and schedules, table 3 shows the internal heat gain factors for each occupied space.

Alongside the three U-value scenarios, the research also has each simulations go through with horizontal overhang louvres and vertical fins, with 1m and 1.5m variants and comparing it to a model with no shades. This is to determine how much solar gain affects the energy performance and PMV in the internal space, as well as how the shading type changes the amount of solar gain entering the windows. Mechanical heating and cooling are set to 6:30am-6pm to make a suitable work environment for the employees during occupied hours on a daily basis, using a heating setpoint of 22 C and cooling setpoint of 24 C (Fergus N. et al, 2013) to achieve neutral temperature range from 22-24 C to ensure that the environment is comfortable. Though operative temperature rises in summer causing PMV to spike and overheat the building. To combat this, a Night Purging Strategy (NPS) could be implemented only during summer, which may allow internal space to cool before use, achieving thermal comfortable values in summer. The NPS used has 20% of the overall glazing of the walls openable, using top hung windows operating from 22:00 to 06:00 and opening threshold set to 25 C or higher, pre-cooling the building before it would be used the next day.

Table 3: Internal Heat Gain for each occupied space



Occupied Space	Sensible Gain (W/m²)		
	No. of Occupants	Lighting	Equipment
1201.Open Workstation	22	10	15
1202.Standard Office	1	10	5
1203.Standard Office	1	10	5
1204.Standard Office	1	10	5
1207.Staircase	X	5	X
1214.Main Circulation	X	10	X
1215.Conference Room	8	10	5
1217.Finance Office	6	10	15
1218.Meeting Room	8	10	5
1219.Office	2	10	5
1220.Open Workstation	24	10	15
1224.Office	3	10	5
1228.Office	1	10	5
1230.Open Workstation	6	10	15
1231.Executive Office	1	10	5
1232.Executive Office	1	10	5
1233.Open Workstation	18	10	15

RESULTS & DISCUSSION

Energy Consumption

To first analyse the energy performance results, an understanding of the current benchmark or amount of energy being used is needed, where energy consumption is typically measured in Kilowatt hours per square meters, being the total amount of energy used per hour, such as lighting, heating and equipment in a given square meter. Conferring to Europa statistics (2013), the average annual kilowatt hours per square metre for European countries stands approximately 250 kWh/m2, though countries closer to Moscow, nearer to Russia's border such as Finland, Estonia, and Latvia ranges from 292.58 to 403.08 kWh/m2 as shown in figure 3, which may suggest that the Western region of Russia encompassing Moscow, may also have an approximate average of 300 kWh/m2. However, the simulation results considers the entire building's envelope of 72x48m, as well as its 12-13 floors, therefore, energy consumption for the building measures up to over 250 Megawatt hours a month.

The simulations shows that there are no significant differences in trends between scenarios, as seen in figure 4 & 5, where figure 4 shows the 1.5m vertical fin, which has the poorest results while figure 5 shows 1m overhang with the most optimal results. Where the only factor that could be seen to cause a change is the standard of U-values. All configurations share a similar trend, starting at the peak in January, using 352.73-472.95 Mwh (352,730-472,950 KWh), though it begins a steep decrease until June, where energy use is at its lowest range from 261.35-263.94 Mwh (261,350-263,940 KWh) where the summer heat could provide natural heating during occupied hours reducing need for mechanical heating until the end of august, where energy consumption increases until December, which uses 349.17-465.96 Mwh (349,170-465,960 KWh) looping back to January.

The annual pattern can be logical, as through the colder months, the building relies on mechanical HVAC to create an artificial micro-climate in order to ensure the building remains operational at an acceptable threshold of thermal comfort. Though transitioning from winter to summer, it allows more reliance on solar gain and natural heating in instead with summers reaching as high or higher than 24 C, reducing the overall use of energy from June to August.

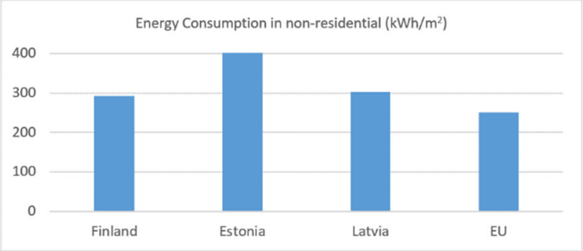
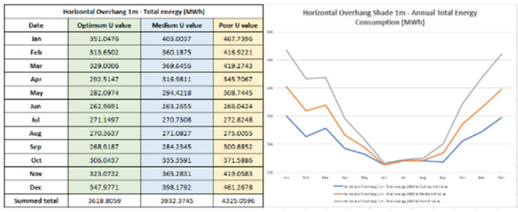
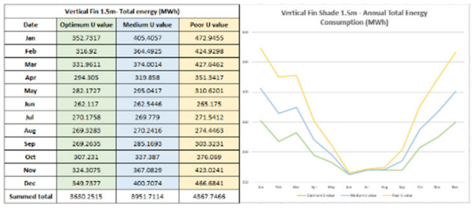


Figure 3. Average energy consumption per m^2 in European countries near Moscow;
Source: (EU Commission)

Improvement in energy consumption may be possible, when using the optimum U-values and comparing it to the poor standard, efficiency improves by 16.6%; however, when compared to the medium values, efficiency is around 7.97% improved. This may suggest that though improvement may be substantial, it raises the question of whether the improvement in efficiency is worth optimising the U-values, as improving the poor U-Values may be justifiable but to improve the medium values which has under 10% improvement may not prove to be enough, following the same trend in efficiency as the glazing type for each standard where there's a larger gap between single glaze and double glaze and a smaller gap between double and triple. While also mentioning that the type or length of shading has little effect on energy performance, with differences between all combinations as well as no shading only varying a +/-12Mwh at most.



Horizontal Overhang 1m - Total energy (MWh)			
Date	Optimum U value	Medium U value	Poor U value
Jan	351.0476	403.0037	467.7396
Feb	313.6502	360.1875	416.9221
Mar	329.0006	369.6456	419.2743
Apr	292.5147	316.9811	345.7067
May	282.0974	294.4218	308.7445
Jun	262.9691	263.2655	266.0424
Jul	271.1497	270.7308	272.8248
Aug	270.3637	271.0827	275.0055
Sep	268.9187	284.2345	300.8852
Oct	306.0437	335.3591	371.5886
Nov	323.0732	365.2831	419.0583
Dec	347.9771	398.1792	461.2678
Summed total	3618.8059	3932.3745	4325.0596

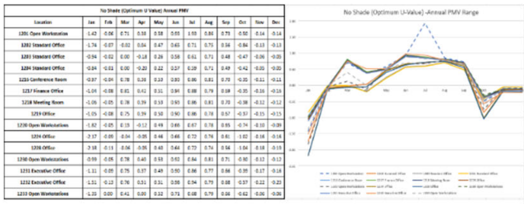


Vertical Fin 1.5m- Total energy (MWh)			
Date	Optimum U value	Medium U value	Poor U value
Jan	352.7317	405.4057	472.9455
Feb	316.92	364.4925	424.9298
Mar	331.9611	374.0014	427.6462
Apr	294.305	319.858	351.3417
May	282.1727	295.0417	310.6201
Jun	262.117	262.5446	265.175
Jul	270.1758	269.779	271.5412
Aug	269.3283	270.2416	274.4463
Sep	269.2635	285.1693	303.3231
Oct	307.231	337.387	376.069
Nov	324.3075	367.0829	423.0241
Dec	349.7377	400.7074	466.6841
Summed total	3630.2515	3951.7114	4367.7466

Figure 4: 1.5m Fin shading -Annual Energy Use **Figure 5:** 1m Overhang Shade-Annual Energy Use

Annual PMV Results

Using the no shade scenario as a baseline pattern, allowing a comparison between the baseline and the various shading scenarios to be carried out in order to evaluate the significance between shading. With no shading, U-values play a similar role as it did with energy consumption, which decreasing the overall range from -3 to +2.29 at a poor level to the range of -1.74 to +1.93 when optimised standard seen in figure 6. Though with NPS, the summer peak from figure 6 reduces from +1.93 to +1.55, due to additional cooling out of occupied hours,



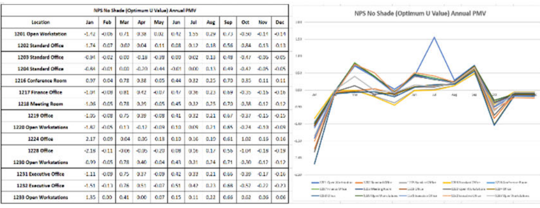


Figure 6: No Shading (Opt.) Annual PMV **Figure 7:** No Shading (Opt) Annual PMV with NPS

When comparing overhanging shading to the baseline, the peak of 2.29 has reduced to 1.19 when using 1m overhang while the 1.5m overhang will decrease the peak further to 1.02, reducing over half the original value. While, if the situation were to be optimised U-values with NPS such as the baseline 1.55, figure 8 shows an improvement of 1.14. deducting 0.41 from the baseline value, while figure 9 achieves a score of 0.81, almost halving the original score, improving by 0.74. A possible reason for this outcome would be due to the increase in length, the louvres would block out overhead direct sunlight against the curtain wall, while having a larger shadow range throughout the day.

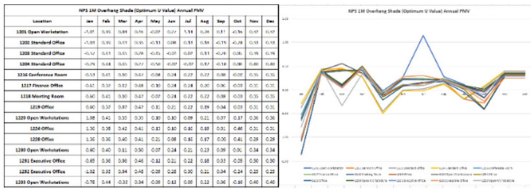


Figure 8: 1M Overhang (Opt.) Annual PMV NPS

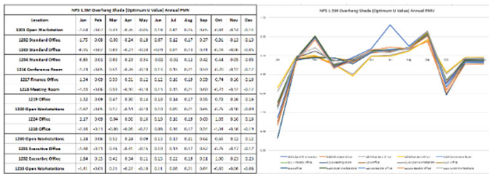


Figure 9: 1.5M Overhang (Opt.) Annual PMV NPS

However, using the vertical fin in the poor U-Value scenario, the peak value score around 1.71 when using 1m vertical louvre fins, while 1.5m louvre fins has a peak of 1.59. Whereas at top U-values, figure 11 is able to achieve 1.29, while figure 10 follows up with 1.34. Though it is somewhat surprising that the medium was able to achieve 1.27 without the need of a NPS, utilising 1m length louvres together with average U-value standard in current day, although it is not as impressive as the improvement made in overhang shading, the result is still able to reach just under half of the original baseline, going from 2.29 to 1.27.Although, vertical fin louvres do provide a substantial development when compared to the no shade baseline alone, ultimately, the results do not reach the extent of the improvements made by the overhang shading, while also not requiring compromising insulation during winter. Therefore, in an annual perspective, use of 1m or 1.5m overhang using an optimised set of U-values and integrated NPS would be the most efficient, however the research requires further in detail analyses, such as how effective PMV may be on a day-to-day basis.

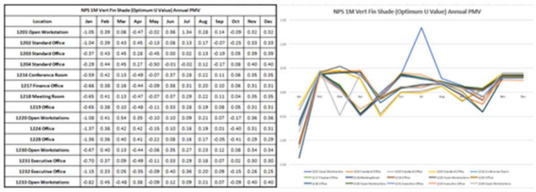


Figure 10: 1M fin (Opt.) Annual PMV with nps

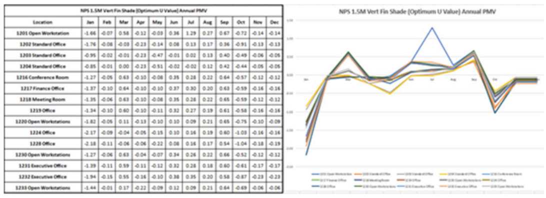
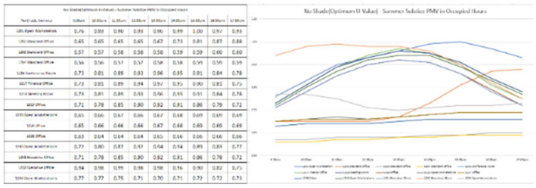


Figure 11: 1.5M fin (Opt.) Annual PMV with nps

Daily PMV Solstice

By analysing the data on a daily scale, rather than annually, it would allow a more thorough breakdown of the PMV and thermal comfort to be taken, where each room's performance can be individually assessed.

Firstly, the no shaded baseline during summer seems reliant on the sun's path, this could be evident by the curving patterns throughout all or most of the rooms throughout figure 12, the southern rooms follow a standard curve, starting around 0.75-0.78 at 9am, peaking around 12-13pm at 1.15-1.21, and ending at 5pm from 0.79-0.85. Though, other rooms may not follow this trend due to its location, therefore, those rooms may peak earlier or later, such as 1232/1233 peaking from 10-11am as they're situated on the east side, while 1201 and 1202 peaks from 15-17pm as they're on the west. However, there are also rooms not exposed directly to the solar gain, being the northern side, resulting in a flat line result with minor fluctuations of +/- 0.03 PMV.



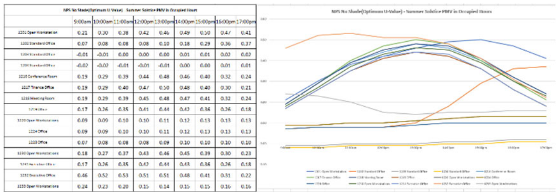
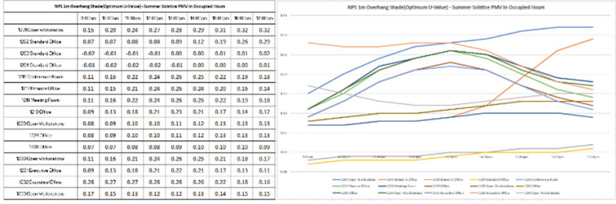


Figure 12: No Shading (Opt.) Summer PMV **Figure 13:** No Shading (Opt) Summer PMV nps

Secondly, the horizontal overhang model essentially produced the more optimal results, while the 1m variant within figure 14 shares a similar pattern to the no shading baseline, it is able to stay within the +/-0.5 PMV as the values ranges from -0.04 to +0.4. While the 1.5m overhang manages to produce a different pattern compared to the other scenarios during summer as shown in figure 15, the occupied spaces follow a shallow fluctuating curve through the day, though rooms on the west area such as 1201 and 1202, increases towards the evening, where other rooms follow a shallow curve peaking 0.68-0.7



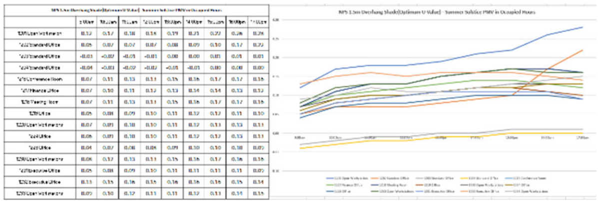
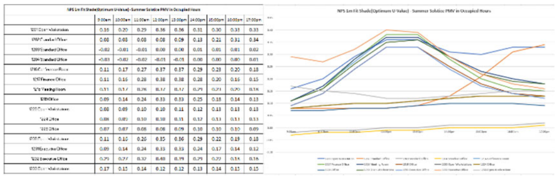


Figure 14: 1m Overhang (Opt.) Summer PMV nps Figure **15:** 1.5m Overhang (Opt) Summer PMV nps

Finally for the summer solstice, the vertical fin shares similar results to the baseline data, as the results within 16 and 17 conveys that most rooms generally having the same patterns in both summer when compared to the model with no shades. With the main difference being that instead peaking, the curve plateaus from 12-13pm, typically around the value of 1.01 - 1.03, this could be due to vertical fins casting a shadow and blocking direct sunlight from infiltrating the window head on, rather than overhead. Though, not impacting the results enough where it may differ from having no solar shades.



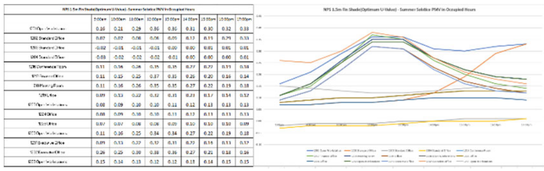
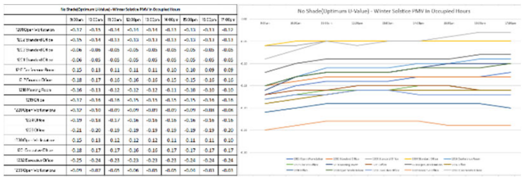


Figure 16: 1m fin (Opt.) Summer PMV nps **Figure 17:** 1.5m Overhang (Opt) Summer PMV nps

When incorporating NPS into the simulations, the patterns throughout any scenario is not affected significantly, though the main difference would be the change in the values. As an example, for no shading, the range was from 0.56 to 1.00, however with integrating the night purging strategy, the range narrows to -0.02 to 0.53, essentially, achieving thermal comfort. This process yields similar results for most scenarios except for the 1m overhang which has kept the original range of -0.03 - 0.32, with values decreasing slightly in between, as well as the 1m vertical fins which remains from -0.02 – 0.40. Although, the 1.5m configuration had a bigger improvement, going from 0.55-0.78 to -0.04-0.28, which allows the 1.5m overhang to remain neutral and balanced on the thermal comfort scale. While the 1.5m vertical fins had improved from 0.55-0.86 to -0.03 to 0.38.

These results convey a pattern, where 1m variants does not improve as much as the 1.5m counterparts, a possible explanation for this reaction may lie in the reason for incorporating NPS from the start. As NPS was integrated in order to keep the commercial building from overheating, however from the data stated earlier, both 1m optimised ranges falls within the +-0.5 PMV, therefore would not require any improvements as the NPS was set to activate when the temperature reaches 25 C or higher, to allow the windows to open in order to pre-cool the building before use, though if the 1m variants remains neutral, then that would suggest the operating temperature would be between 22-24 C in order to meet CIBSE Guide A’s temperature comfort criteria.

Unlike the daily summer PMV, within winter, the solar path does not directly influence the PMV, with the main differences between the two results being the pattern, using the no shading 1217 as the baseline, during summer, the PMV would curve from 0.73 at 9am, where it continues to increase until 1pm peaking at 0.97, where it would then decrease until 5pm, ending around 0.73. However, during winter, 1217 would start at -0.18 and where it would peak in summer at 1pm, the score increases to -0.16 and would increase further to -0.15 until 3pm where it remains -0.16 up until 5pm. With the largest difference in PMV being 0.03, which would be unnoticeable in terms of thermal comfort. Overall having a shorter range than it would in summer, with a range of -0.25 to -0.03.



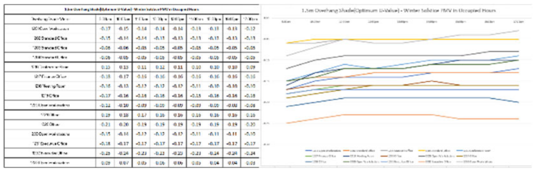


Figure 18: No Shading (Opt.) Winter PMV **Figure 19:** 1.5m Overhang (Opt) Winter PMV

Figure 18 and 19 compares the no shading to a 1.5m overhang, however as seen, the results are almost exact and highly similar. Due to the lack of influence from solar gain or external climate conditions, it seems possible that these results are created in a completely artificial environment, creating somewhat of an internal micro-climate where the temperature would be manipulated through mechanical heating, ventilation, and air conditioning (HVAC). However, if the solar gain has no effect on winter PMV, then it would also suggest that the shading could be redundant during winter.

As previously stated, during winter, the ranges in each scenario compresses, allowing some cases such as no shading to fit within the neutral threshold to succeed in thermal comfort. Similar results can be when using optimised values, whatever the range was before such as 1.5m fin’s 0.55-0.86 or 1.5m overhang’s 0.55-0.78, it will be fixed to -0.25 to -0.03, just as it was during no shades. This may be due to the autonomous nature of creating a thermally comfortable space solely using mechanical HVAC, creating a fixed range depending on the level of U-Value, as if a poor U-Value standard was used, the range would then be fixed to -0.69 to -0.08, though this is not to say that the shading results are identical to each other, as the values are varying within the fixed range. This may be advantageous as with an optimised U-Value, it would fix whatever configuration to become thermally comfortable. Where in stark contrast, during summer both the sun path and shading strategy can control when the highest and lowest point in each configuration, where in some cases both values tend to be too warm to classify as neutral.

Operative Temperature Results Ultimately, operative temperature results run parallel to PMV, meaning that trends and patterns will be highly similar to that of PMV’s result, due to the fact that the operative temperature is a huge factor when calculating PMV, alongside internal and latent gains, clothing insulation and activity type among other properties. Therefore, instead of repeating patterns and re-establishing explanations discussed within PMV, there will be a focus on the analysis of the operative temperature, which will allow further insight in context to the PMV results as well as being able to assess internal temperature within the occupied spaces, for areas where a PMV scale may not prove to be enough.

Throughout most simulations beforehand, room 1201 seems to be the room that always peak in terms of warmth, this could be due to where the office is situated, allowing for more exposure to solar gain through the day by taking up 1/6 of the southern façade of the top floor, but also having a second curtain wall, meaning that two of the four walls are glazed, which could explain how the room is prone to overheating as well as heat loss. Using 1m Overhang as seen in figure 20 and 21, in July, 1201 may reach a range from 27.84-28.51 C, being the warmest room, with the second warmest office ranging 25.21-25.45 C, being 1232. Which is a similar case, with two sides being curtain wall, though the office may not be as large as the 1201 space, it may still be vulnerable to the same type of thermal bridging, both rooms score the lowest within January 1201 scoring -6.13 C while 1232 scores 6.1 C, additionally proving that most of the heat loss may be due to both occupied spaces. This would lead to suggest that rooms with 2 curtain wall elements are not as efficient and using more external wall elements would improve that room's performance.


1m Overhang Shade (Poor U Value) Annual Temperature

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1201 Open Workstation	6.13	19.83	23.86	18.98	22.56	25.40	28.51	24.23	23.40	13.92	19.31	19.32
1202 Standard Office	6.21	20.45	20.99	19.01	21.77	24.49	24.57	24.05	21.77	13.71	20.11	20.13
1203 Standard Office	14.91	21.55	21.67	19.73	21.85	24.08	24.04	24.04	21.90	18.14	21.57	21.66
1204 Standard Office	16.05	21.63	21.72	19.85	21.83	24.03	23.93	24.02	21.97	18.64	21.64	21.72
1216 Conference Room	10.09	20.24	24.70	19.74	21.74	25.37	25.17	24.10	22.60	15.90	19.82	19.84
1217 Finance Office	9.36	20.03	24.87	19.68	21.72	25.51	25.25	24.08	22.75	15.63	19.55	19.57
1218 Meeting Room	9.35	20.18	24.67	19.64	21.74	25.36	25.14	24.06	22.59	15.59	19.76	19.80
1219 Office	9.40	20.15	24.66	19.64	21.73	25.36	25.13	24.06	22.55	15.61	19.71	19.75
1220 Open Workstations	6.62	20.63	21.01	18.89	23.14	24.47	24.43	24.17	23.65	14.18	20.39	20.46
1224 Office	3.43	19.98	20.55	19.42	21.69	24.51	24.81	24.00	21.88	12.58	19.45	19.41
1228 Office	3.45	19.93	20.52	19.46	21.67	24.49	24.82	23.97	21.86	12.57	19.38	19.33
1230 Open Workstations	9.33	20.19	24.67	19.65	22.33	25.36	25.07	24.11	23.43	15.58	19.78	19.83
1231 Executive Office	9.03	20.09	24.64	19.53	21.72	25.38	25.15	24.06	22.49	15.42	19.64	19.68
1232 Executive Office	6.10	19.35	24.07	19.17	21.54	25.64	25.45	23.95	22.17	13.71	18.63	18.58
1233 Open Workstations	9.64	20.91	21.34	18.99	22.95	24.50	24.38	24.12	23.41	15.31	20.75	20.81

Figure 18: 1m Overhang (Poor) Annual Temp. **Figure 19:** 1m Overhang (Opt) Annual Temp.

CONCLUSION

To precis, the holistic aim of the paper was to assess and improve energy performance and thermal comfort in a Russian Office Building. Various combination scenarios including levels of U-values, types of shading and with and without night purging strategies were considered. The positive results of the research and simulations would sequentially combine to show how both energy performance and thermal comfort could be improved. This configuration uses the optimised set of U-values in order to increase airtightness and insulation, which would in turn keep the building warm and reduce energy consumption, using triple glazing with argon filled cavities for curtain walling and reduce heat losses, also requiring a reduction in wall to glazing ratio to reduce heat losses during winter. The application of overhung shading and night purge ventilation, to precool buildings, are also effective strategies to prevent overheating during summer.

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