FAÇADE OPTIMISATION FOR A PRIMARY SCHOOL

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Thermal, Acoustic, Ventilation & Daylighting Assessment

Revision	Description	Author	Checked By	Issue Date
00	First Issue	Emily Cao	Josh Childs	19/04/2017

MACH Energy
3rd Floor, 4 York Court
Upper York Street
Bristol
BS2 8QF

Tagwright House
35-41 Westland Pl
London
N1 7LP

t: 0117 944 1388
e: info@machacoustics.com
w: www.machacoustics.com

Consultants	Emily Cao	emily@machacoustics.com
	Josh Childs	josh@machacoustics.com
	Max Reynolds	max@machacoustics.com
Finance	Tracy Toal	tracy@machacoustics.com
	Zheng Ge	zheng@machacoustics.com

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1.0 INTRODUCTION

This report looks at the optimisation of a façade of a small primary school block, so to achieve the best possible performance in regards to acoustics, daylight, ventilation and energy use.

The classroom block assessed in this report is fictional, however it is based on numerous similar projects that MACH have worked on before. The main design features of the block are that it is single storey and has a fully-glazed south-facing façade with a large shading canopy, as shown in the figure across.

For the assessment, 3 lengths of shading canopy are proposed for the assessment room, so to determine which length better suits the overall performance.

Design Criteria

The assessment will be in reference to guidance provided in BB101, so to ensure overheating and thermal comfort are suitably controlled.

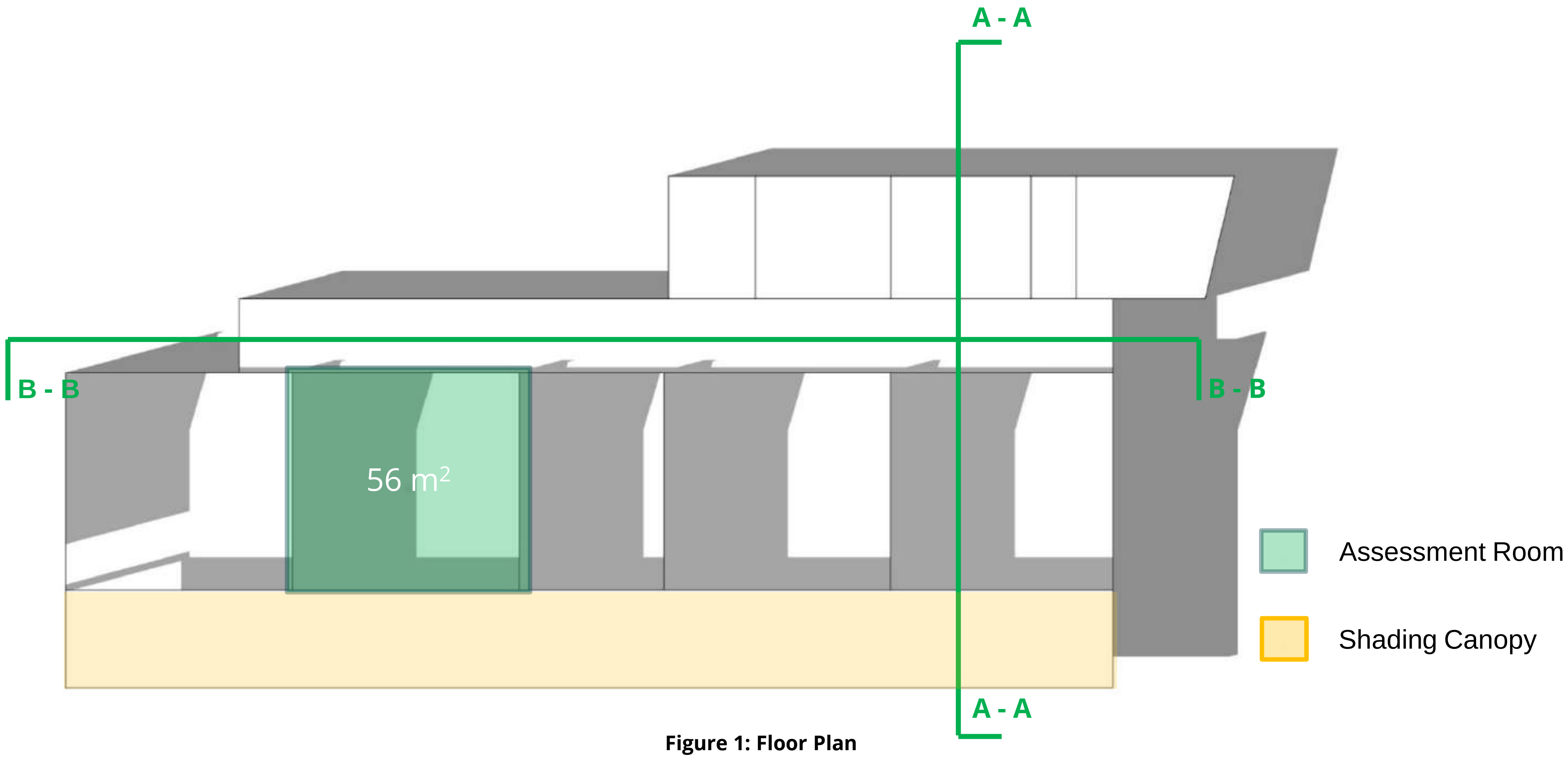


Figure 1: Floor Plan

A-A Section

B-B Section

1.1 BALANCING THE PERFORMANCE

The environmental design of a classroom, or any other building, is a balancing act between many factors. For example, excessive shading reduces solar gains but also decreases daylight; while ineffective shading may result in overheating and unwanted glare.

This is also the same for acoustics and natural ventilation, where a larger area of open window increases the ventilation rate but decreases the acoustic performance of the façade.

Everything is interlinked – the shading affects the solar gains, which in turn affects the ventilation requirement for overheating, which increases the open window requirement thereby reducing the acoustic performance.

Therefore, it is important that all these factors are considered together - holistically – so each element can be balanced against the other to get the best performance.

The diagram below gives an illustration on how some of these factors all work together. For this assessment we have kept elements such as the U-values and internal gains as constant, so to determine the relationship between other aspects.

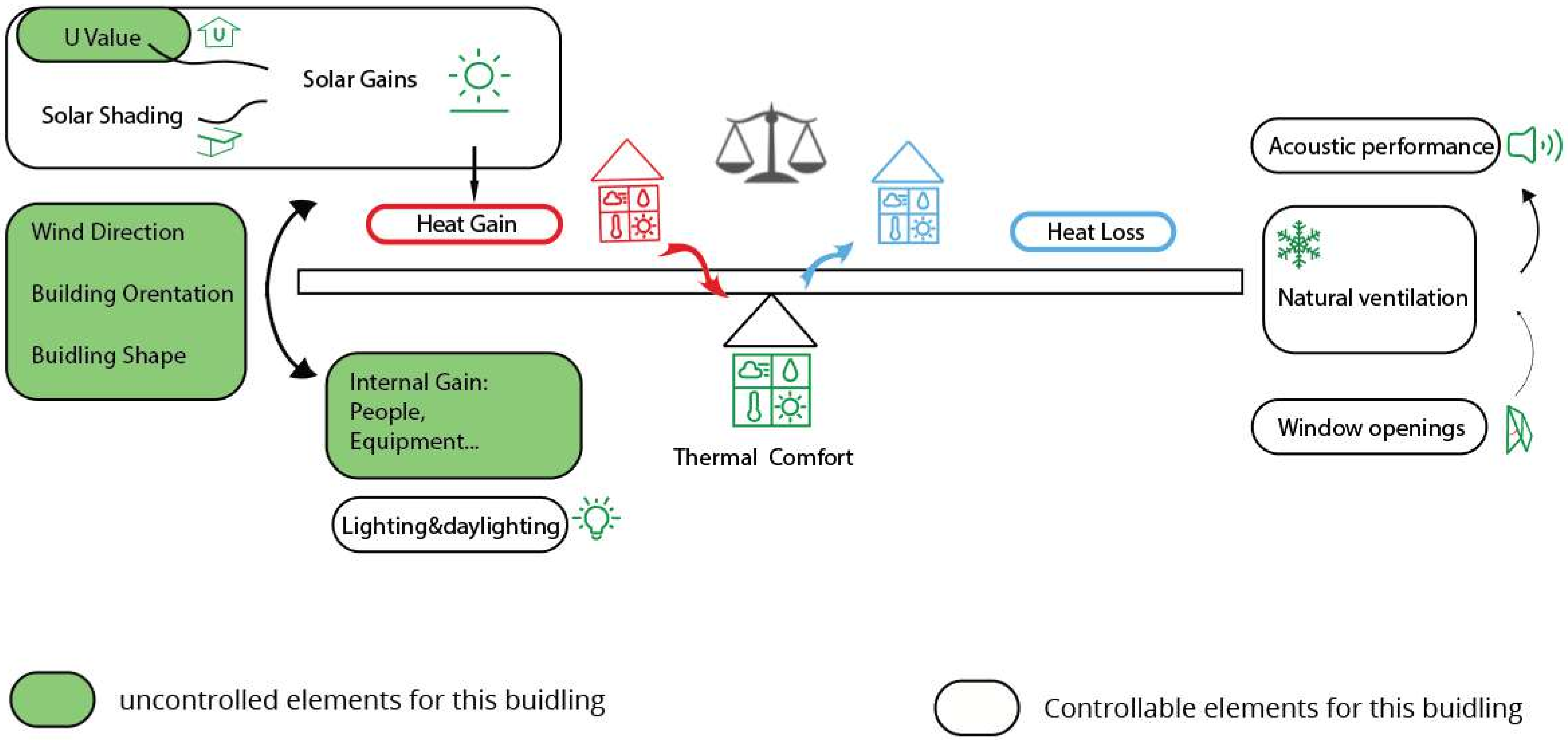


Figure 1 : Thermal comfort balance

1.1 BALANCING THE PERFORMANCE

These same principles can also be expressed through the radar charts, shown opposite. From modelling the space through building physics software, we can determine how each element changes the other and how it all works together.

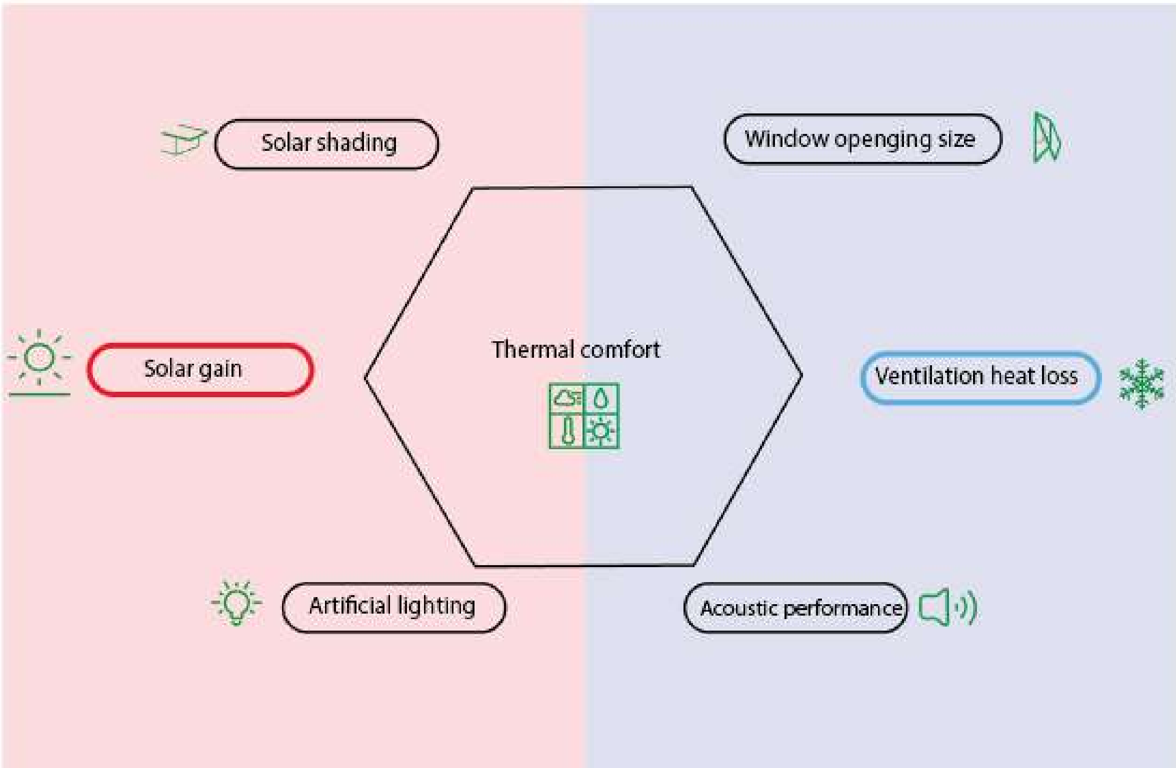


Figure 2 : Thermal comfort elements with full length solar shading

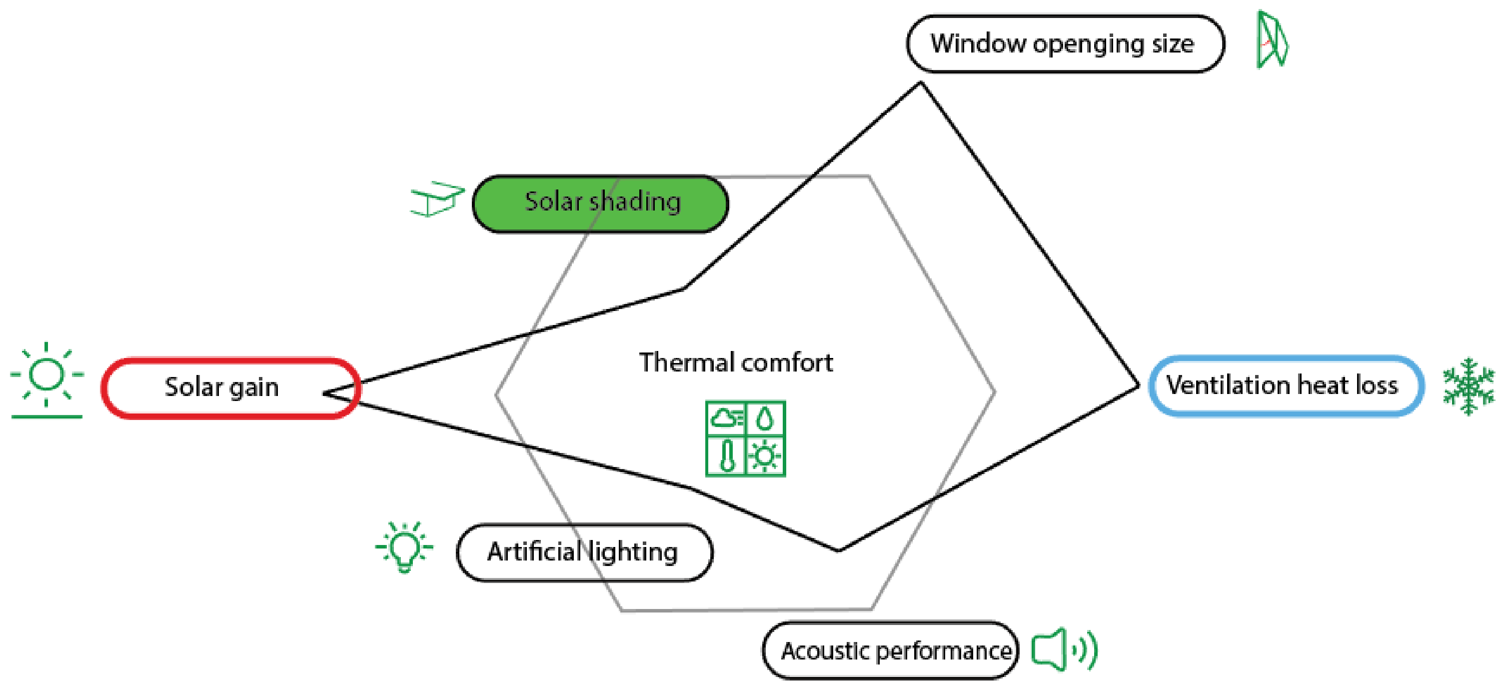


Figure 3 : Thermal comfort elements with half length overhang

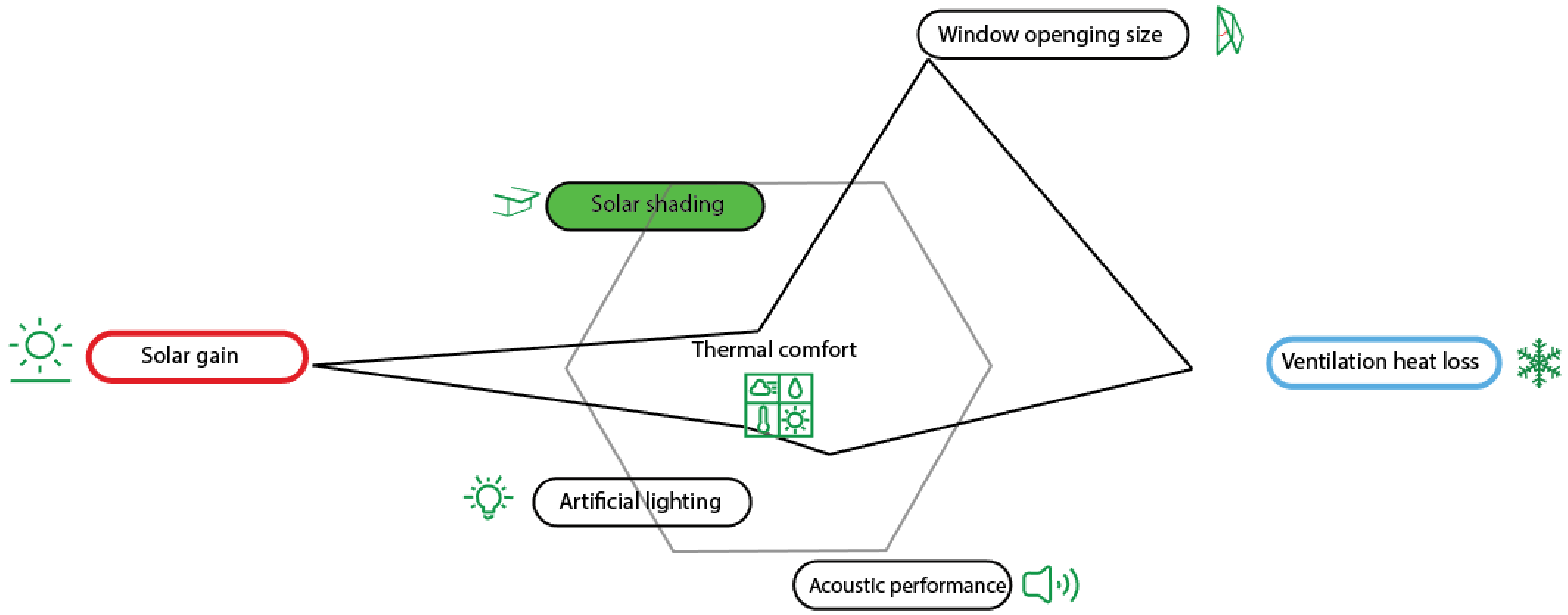


Figure 4 : Thermal comfort elements without overhang

1.3 ASSESSMENT PERIOD

The assessment is determined by the affect of solar shading and overheating, and as such the majority of the analysis will be looking at the peak summer months, as highlighted in orange on the temperature graph opposite. This is taken to be from May to the end of September.

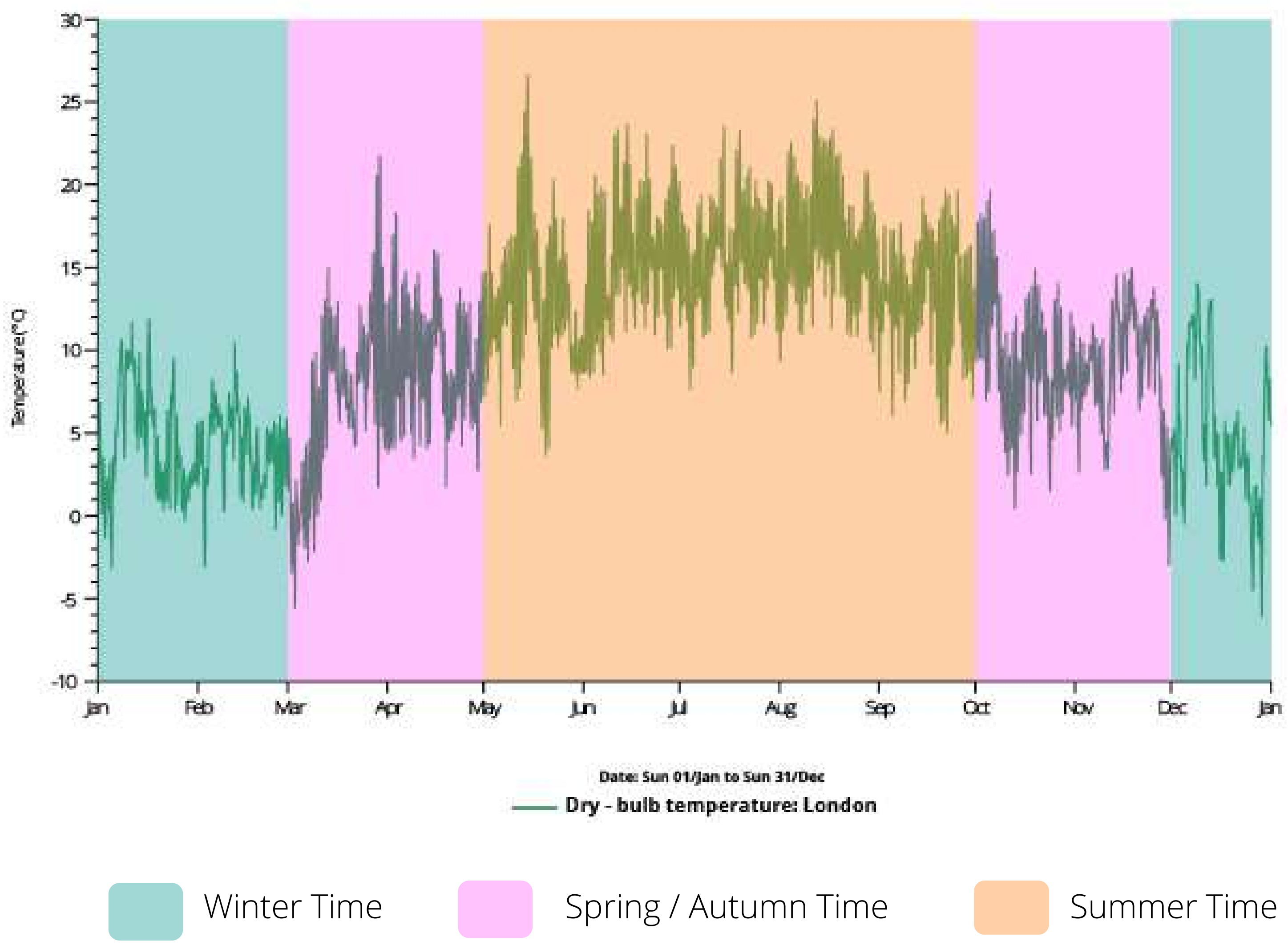


Figure 5 : Annual external temperature and assessment periods

2.0 HOLISTIC SUSTAINABLE DESIGN

A building physics model has been created of the development and has been simulated across the various weather changes over a typical year. The results of this modelling have enabled MACH Energy to determine early stage input in to a holistic design strategy.

Passive Design Strategies

Passive design strategies are maximally used in this project to reduce energy consumptions for this building.

1. Daylighting:
2. Natural ventilation
3. Solar shading

Good daylighting design is a balance between daylight ,glare and solar gains. Effective shading can avoid glare, and also reduce solar gains to avoid overheating. Natural ventilation can ensure the required air change rate to maintain good indoor thermal comfort.

Indoor Thermal Comfort

Indoor thermal comfort includes the carbon dioxide level , indoor air temperature and humidity . For this model, we considered how all aspects link to the holistic design

Acoustics Design

The major noise source on the site is airplane noise, and as such the inclusion of the shading canopy will provide some acoustic screening to the open windows in the façade. As part of the assessment, acoustic modelling is carried out, using in-house Finite Difference Time Domain software (FDTD). This allows use to gain an accurate understanding of the impact of each shading type.

01 COOLING : Natural ventilation

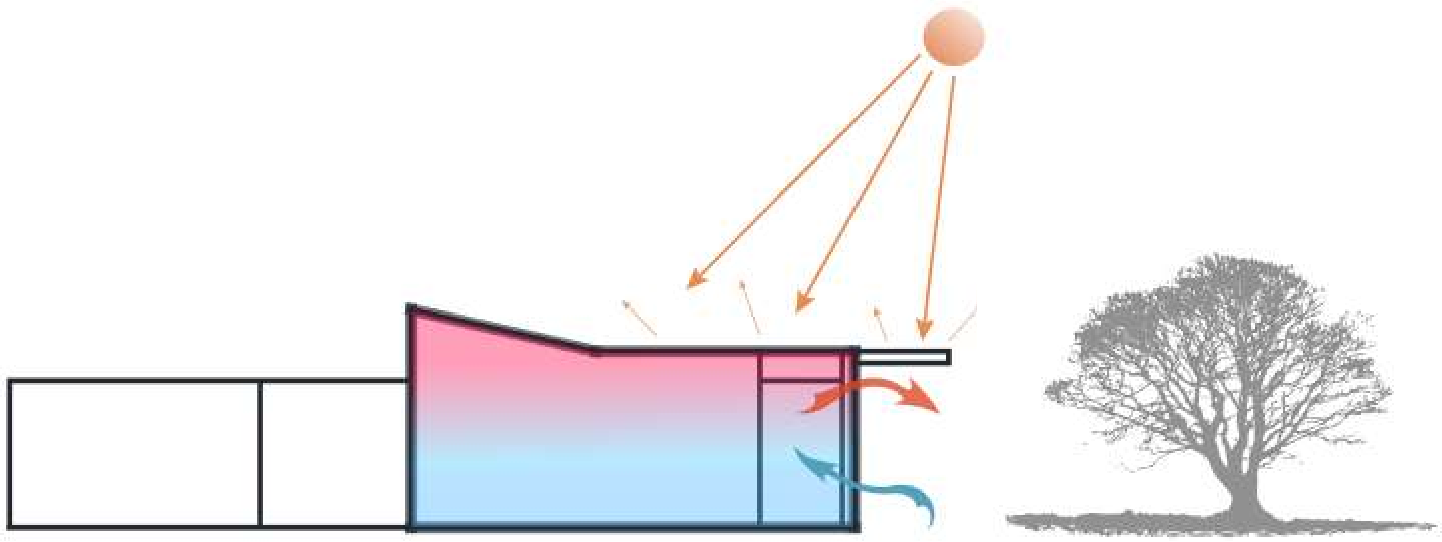
02 LIGHTING : Daylighting

03 ACOUSTIC COMFORT

04 INDOOR THERMAL COMFORT

05 SOLAR SHADING

06 HIGH U-VALUE FABRICS



2.1 SUSTAINABLE DESIGN CONCEPT

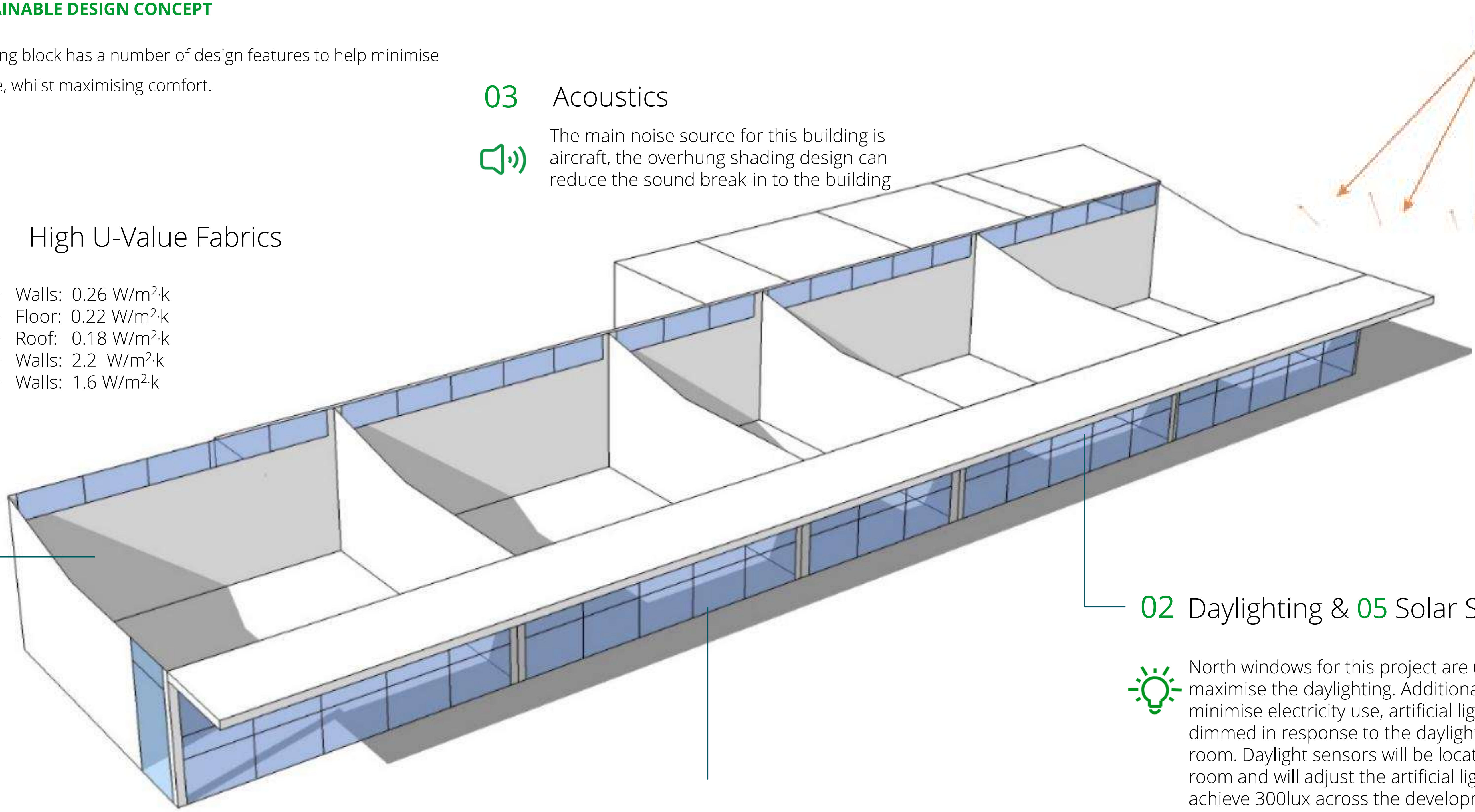
The teaching block has a number of design features to help minimise energy use, whilst maximising comfort.

03 Acoustics

The main noise source for this building is aircraft, the overhung shading design can reduce the sound break-in to the building

06 High U-Value Fabrics

- Walls: 0.26 $W/m^2 \cdot k$
- Floor: 0.22 $W/m^2 \cdot k$
- Roof: 0.18 $W/m^2 \cdot k$
- Walls: 2.2 $W/m^2 \cdot k$
- Walls: 1.6 $W/m^2 \cdot k$



02 Daylighting & 05 Solar Shading

North windows for this project are used to maximise the daylighting. Additionally, To minimise electricity use, artificial lighting will be dimmed in response to the daylight levels in the room. Daylight sensors will be located in each room and will adjust the artificial lighting to achieve 300lux across the development.

An external shade has been included on the south facing façade. It is 1.5m deep and runs along the length of the façade.

04 Indoor Thermal Comfort

Indoor thermal comfort is a combination of indoor temperature, air quality and humidity. For this building, based on BB101 ,we maximised the natural ventilation to supply required thermal comfort level

01 Cooling

During summer time, certain windows are opened for natural ventilation to ensure indoor air quality and thermal comfort. No mechanical services will be used.

Figure 6 : Proposed Design & Key Features

2.2 MODEL SET UP

Ventilation set to be a single sided strategy throughout the building as illustrated to the right. Low and high level windows were set up for buoyancy driven ventilation.

As shown below, three solar shading concepts have been proposed for the classrooms. The assessment will only be carried out for one classroom as it is seen to be similar for all other spaces. The occupancy profile is shown below.

Element	Profile	
Occupancy	100% Occupied :	09:00 – 12:30 & 13:30 – 18:00 Monday to Friday
	Not Occupied :	Weekends and holidays
Windows	Open When :	Operative temperature > 22°C **OR** CO_2 concentrations > 1,200 ppm

Table 1: Profiles Used In The Model

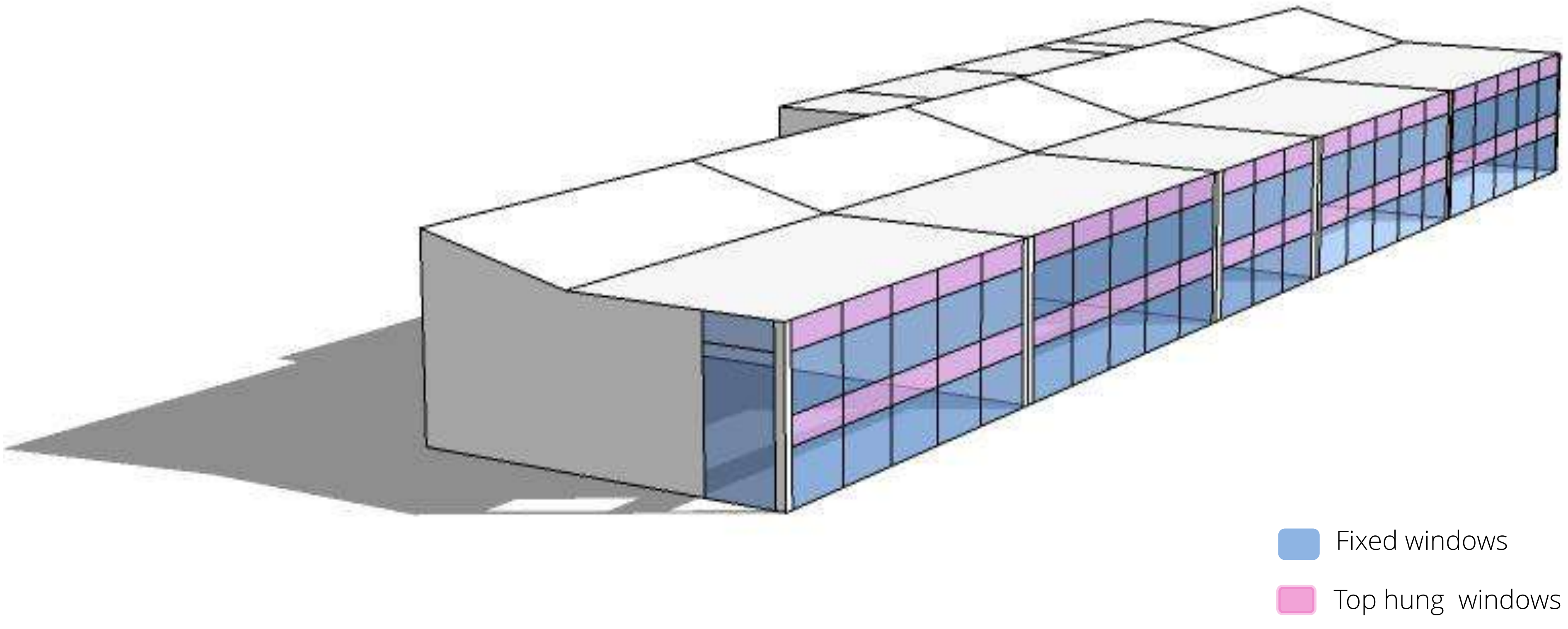
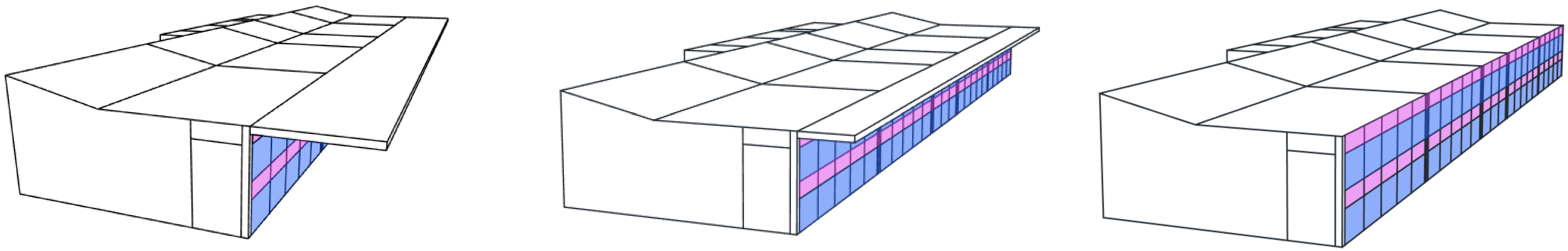


Figure 7 : Proposed Single Sided Natural Ventilation Strategy



Full length solar shading

Half length solar shading

Without solar shading

Figure 8 : Three different solar shading concepts

2.3 BUOYANCY – DRIVEN - VENTILATION

Natural ventilation will be achieved through the use of single-sided ventilation, with high and low positioned top-hung windows on the south facing façade. As single-sided ventilation is not the most efficient method, the high and low positioned windows add some thermal buoyancy to increase the overall ventilation rate.

The windows positioned at high level on the north facing façade are for daylight only and are not modelled as open.

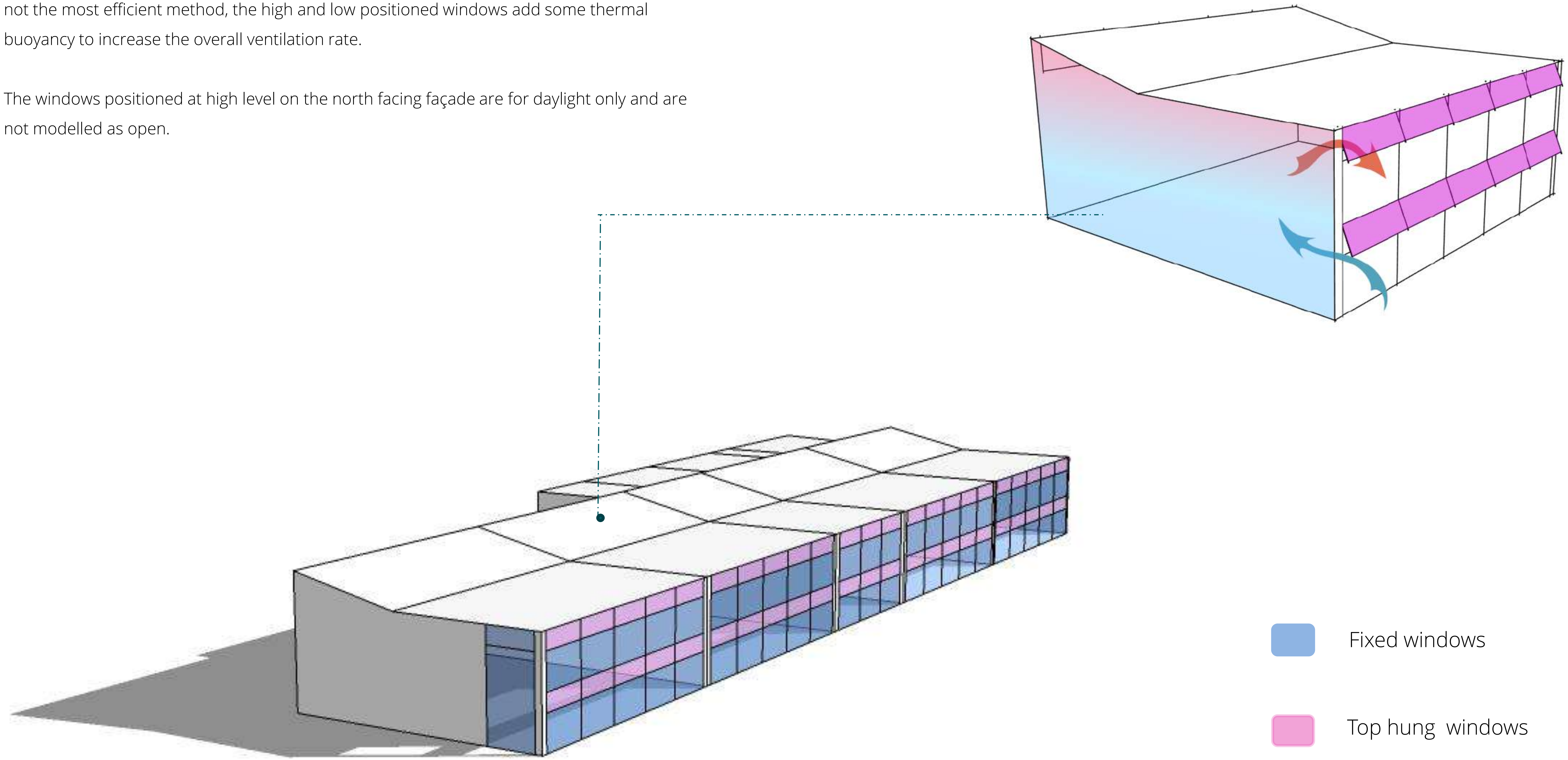
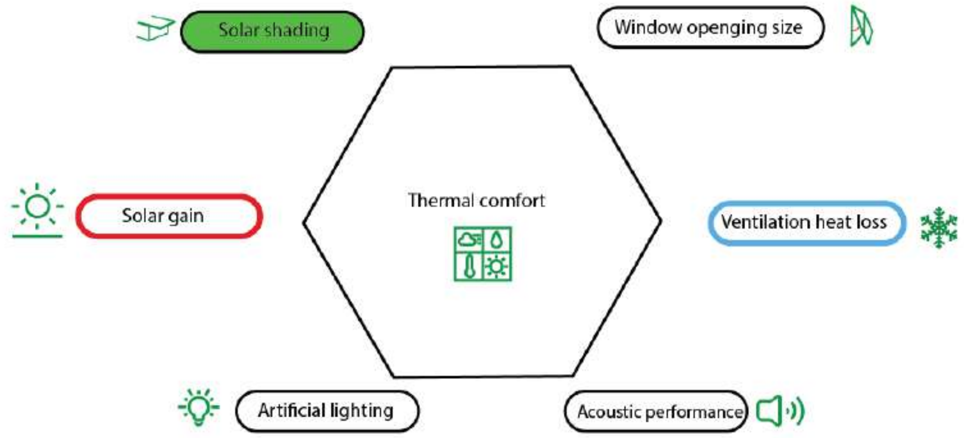
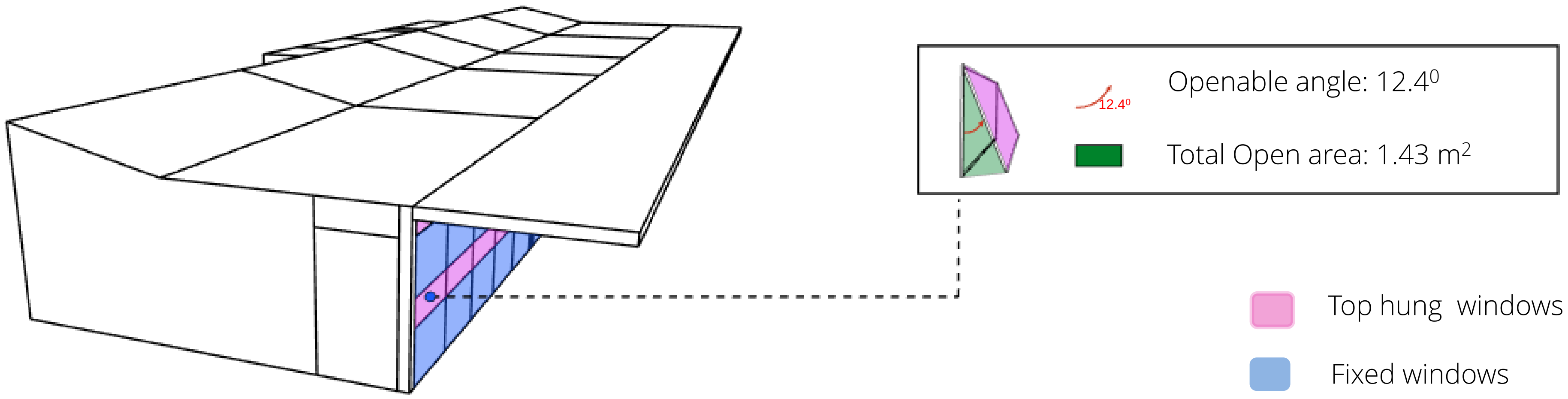


Figure 10 : Detail Single Sided Natural Ventilation Strategy

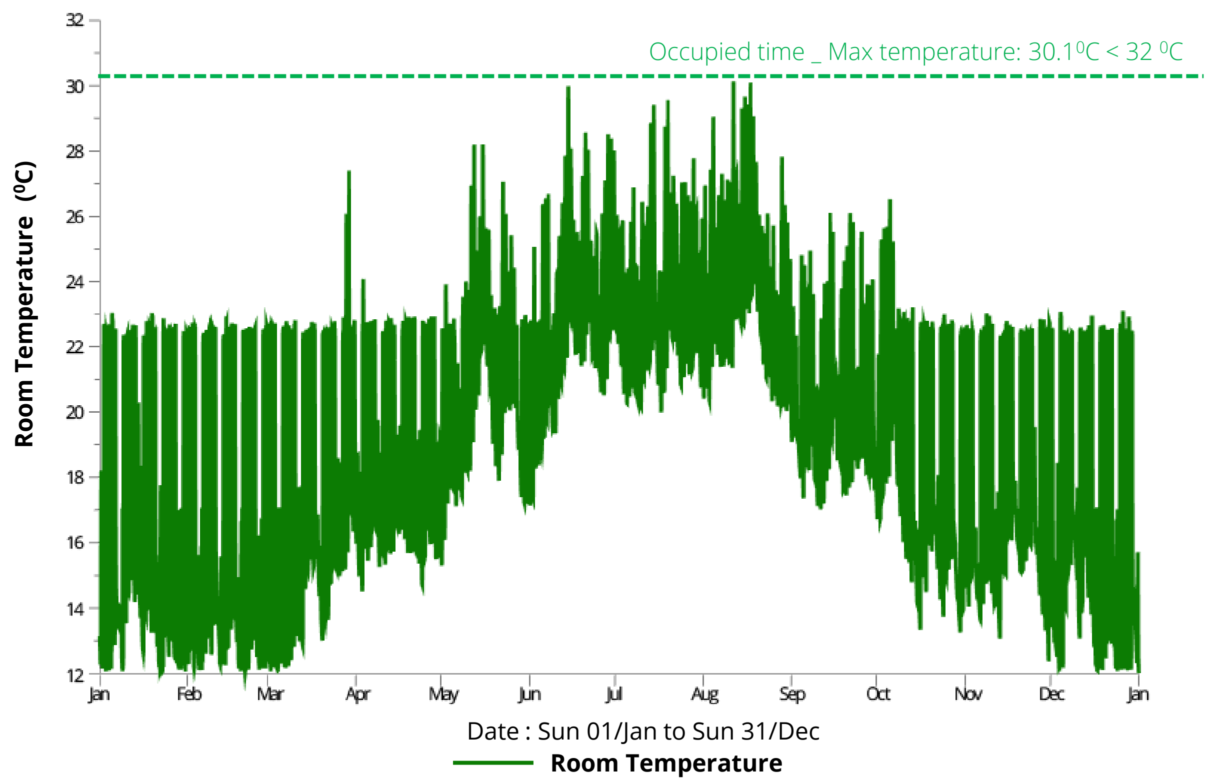
3.0 RESULTS – FULL LENGTH SOLAR SHADING

In order to achieve the thermal comfort for this building with full length shading, the required total open area will be 1.43 m² . The following figures show the modelling results : room temperature (max : 30.1⁰C) , carbon dioxide concentration (consistently below 1500ppm) and average daylight factor (2.4%).

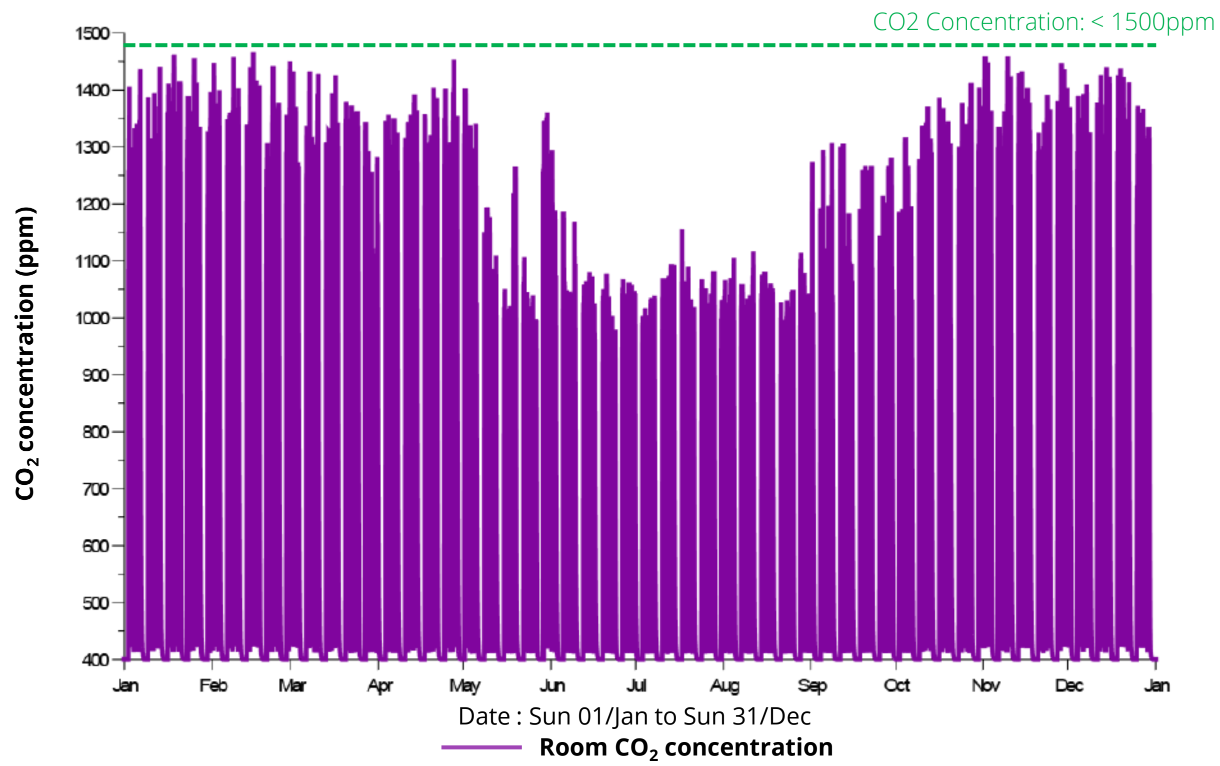




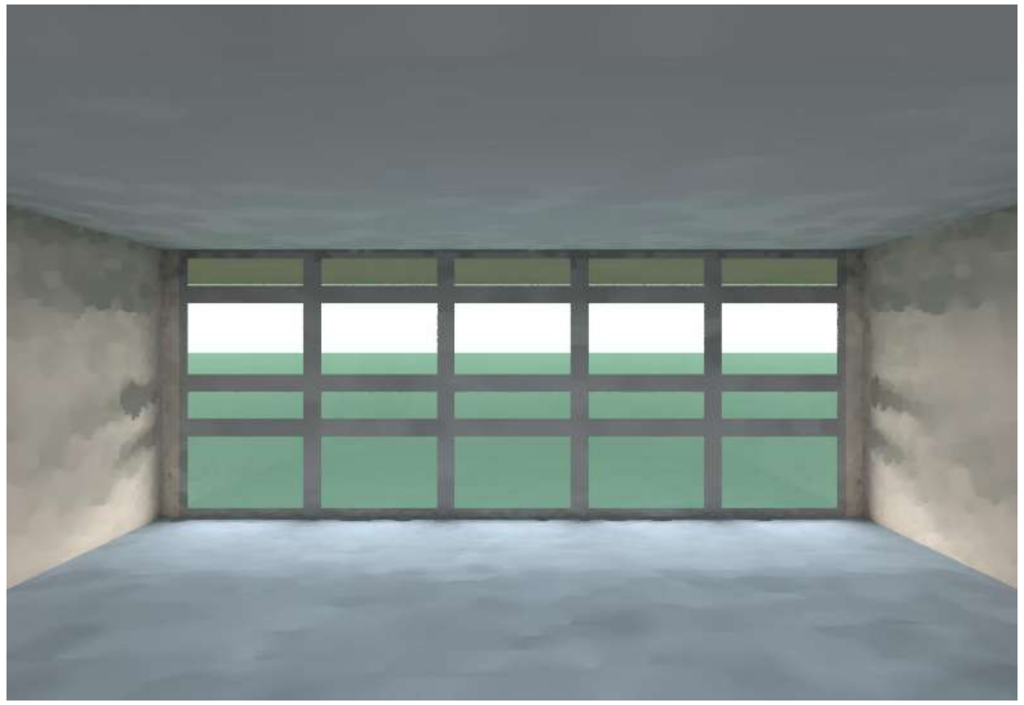
Room temperature:



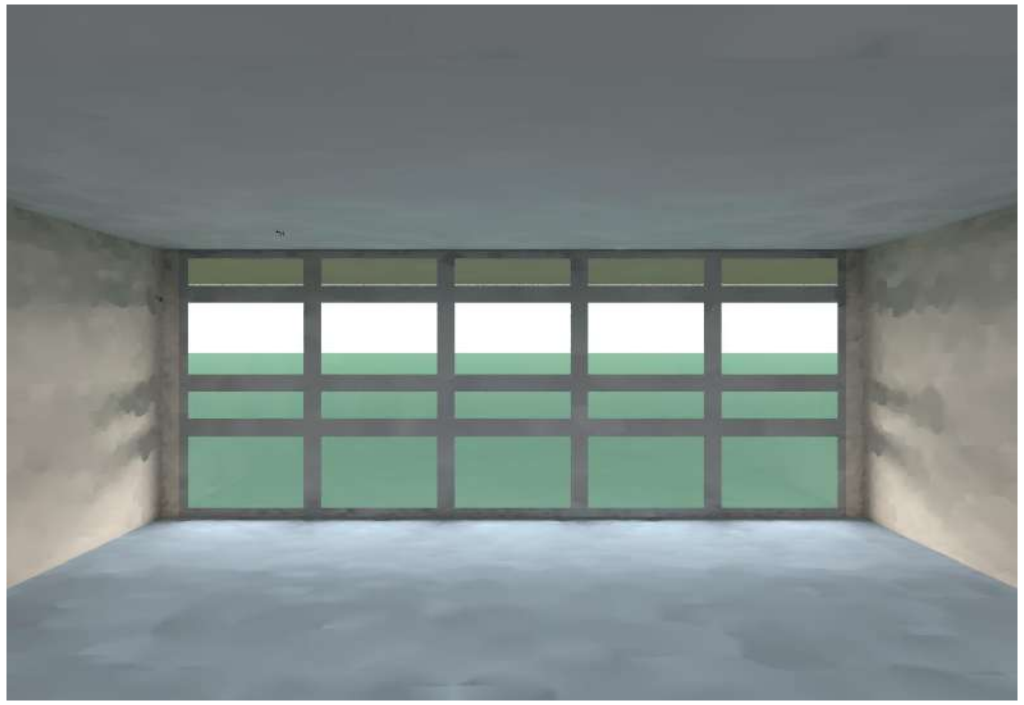
Carbon dioxide:



3.0 RESULTS – FULL LENGTH SOLAR SHADING



10 th. August. 12:00pm



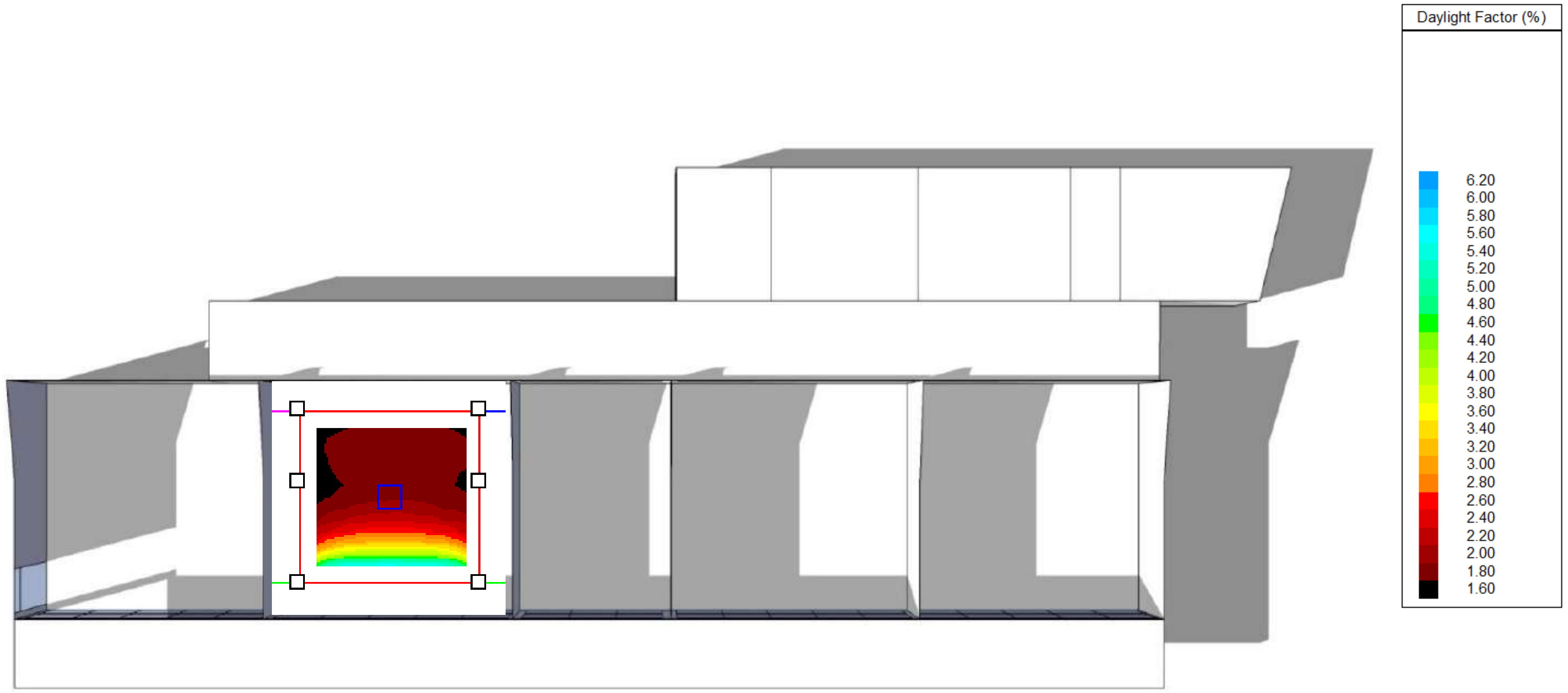
10 th. March. 12:00pm

Internal perspective Luminance view

Daylighting Analysis

Average daylight factor : 2.4%

The average daylight factor for this building with full length solar shading is 2.4% , this result meets the standard requirement for daylighting , shows that this classroom can be fully day lit during brighter days, but artificial lighting is still needed to achieve the required internal illuminance level for the majority of the time.



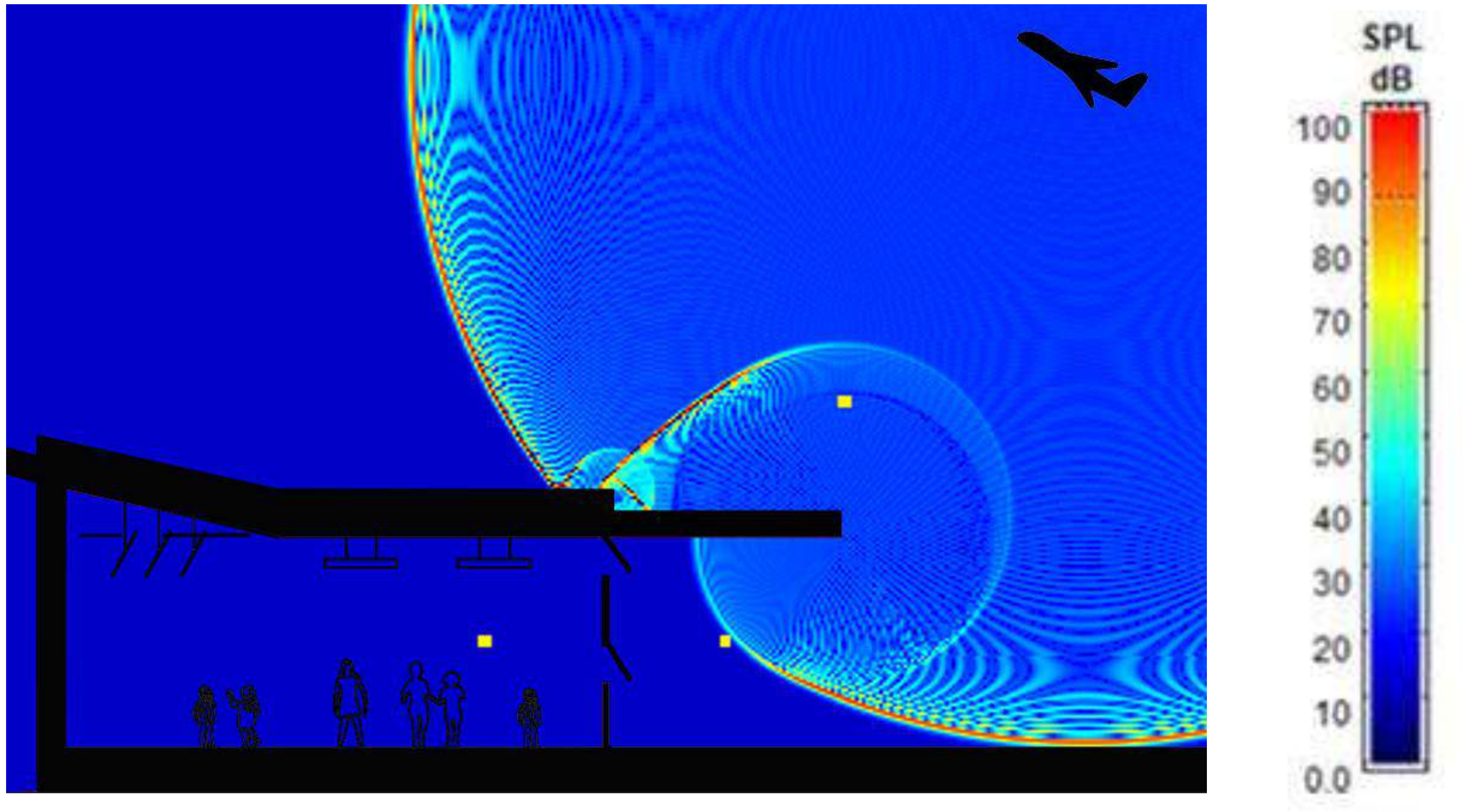
3.0 RESULTS – FULL LENGTH SOLAR SHADING - ACOUSTICS

The images shown across show the modelled acoustic performance of the full-length shading option, using in-house FDTD software. The software allows us to see how sound propagates across the façade from the aircraft in the top right hand corner.

From analysing the software, we are able to compare noise break-in levels between the different shading options. The no-shading option is seen to be the 'normal' acoustic performance (see page 19), and so the increase in performance will be compared to this. As shown below, from adding the shading, an increase of 5dB is achieved.

Façade Design	Noise Level Difference Across Façade Dw	Relative Difference of Façade Performance
Full Shading	27 dB	+5 dB

Table 2: Acoustics performance for full length solar shading



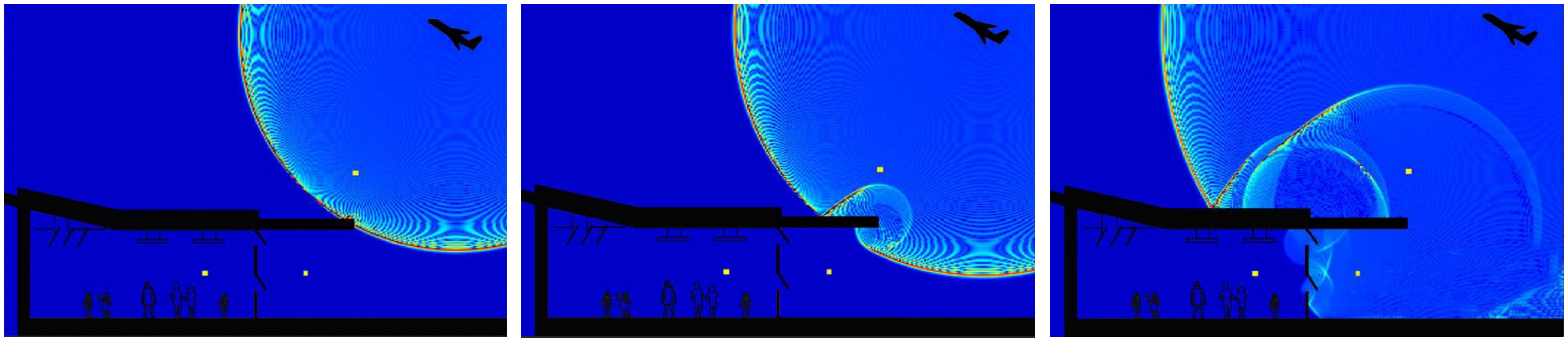
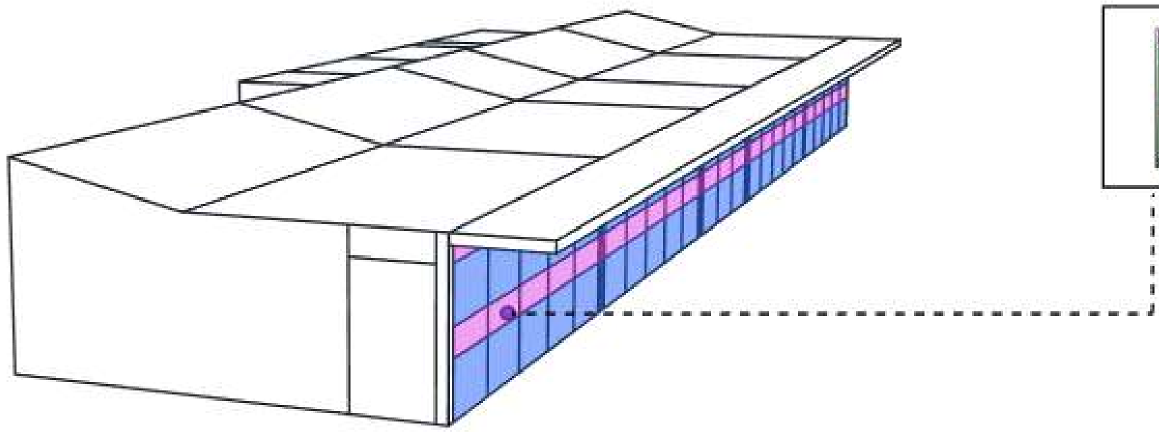
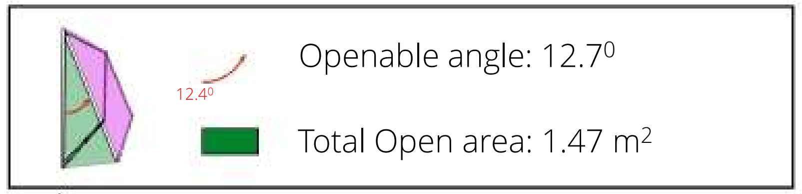


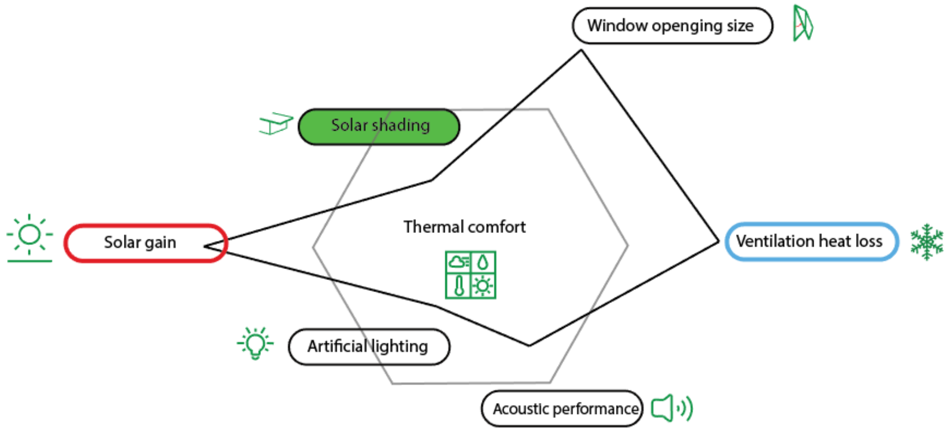
Figure 9. Acoustics performance visualisation for full length solar shading

3.1 RESULTS – HALF LENGTH SOLAR SHADING

In order to achieve the thermal comfort for this building with half length shading, the required total open area will be 1.47 m² . The following figures show the modelling results : room temperature (max : 29.9⁰C) , carbon dioxide concentration (consistently below 1500ppm) and average daylight factor (3.1 %).



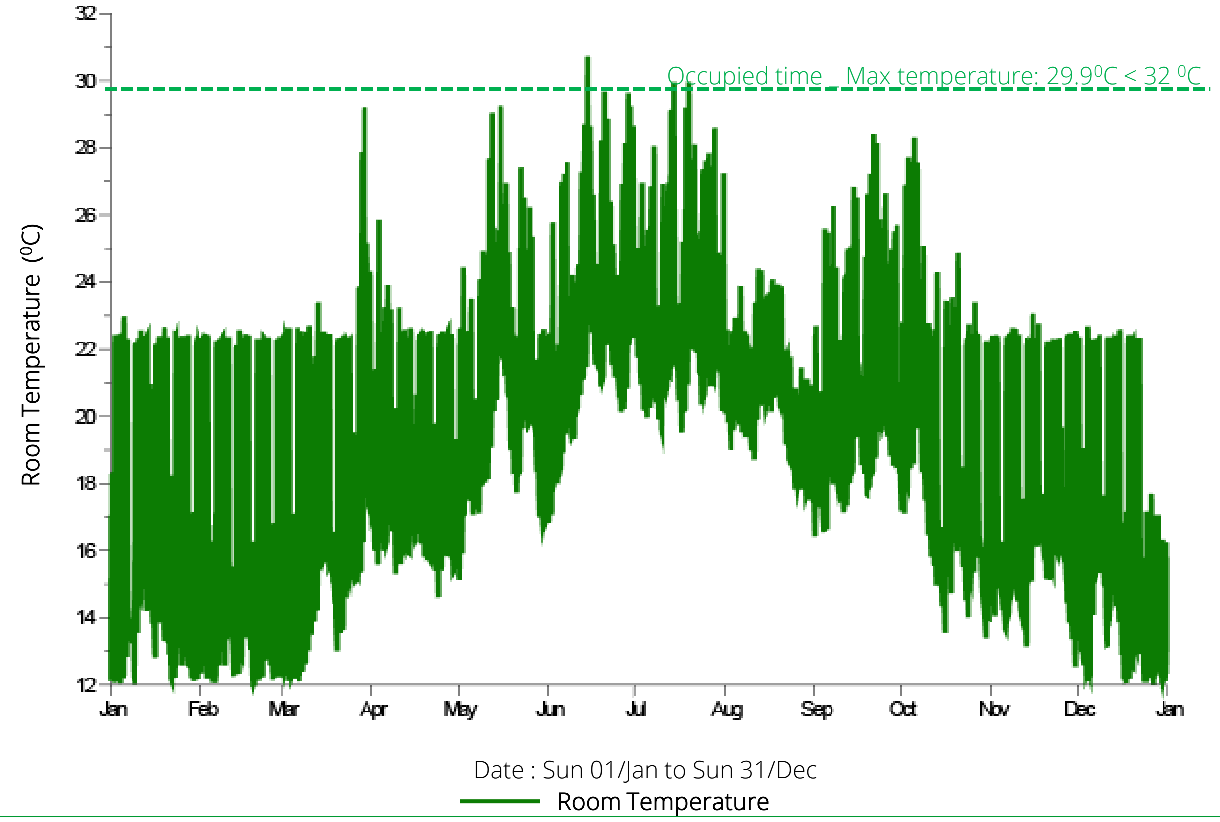




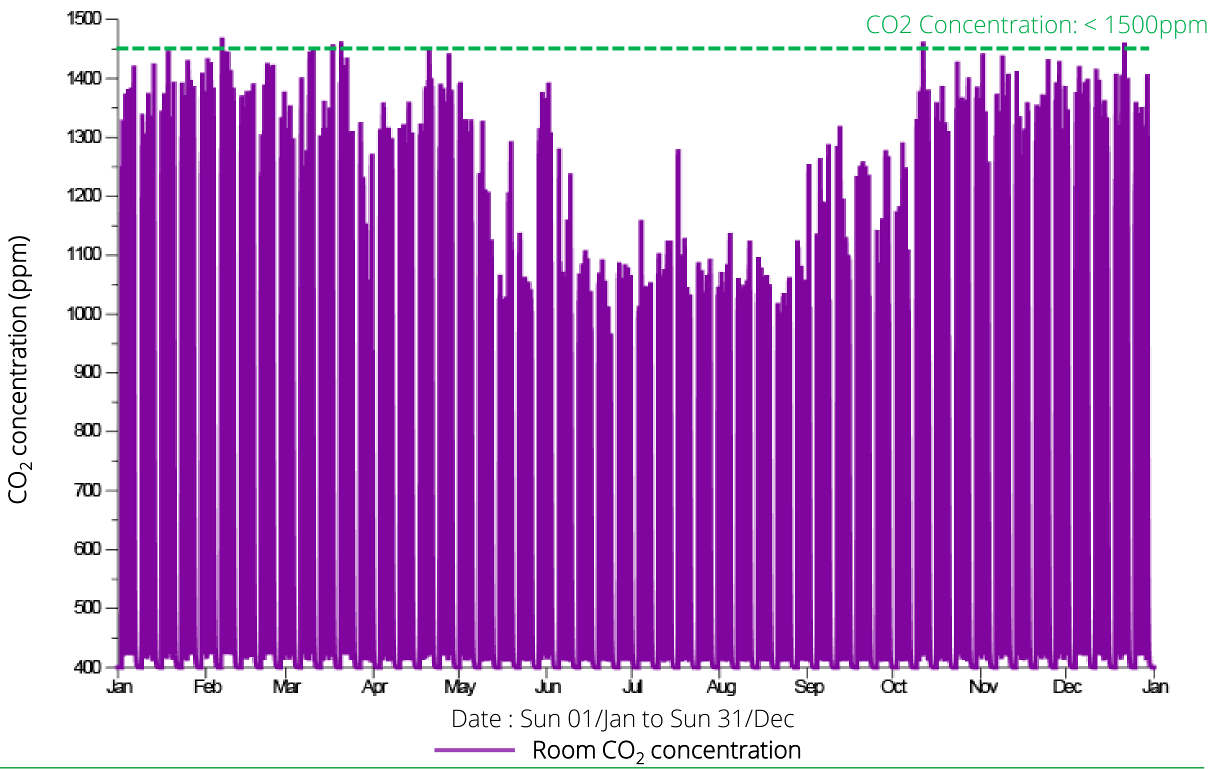
Top hung windows

Fixed windows

Room temperature:

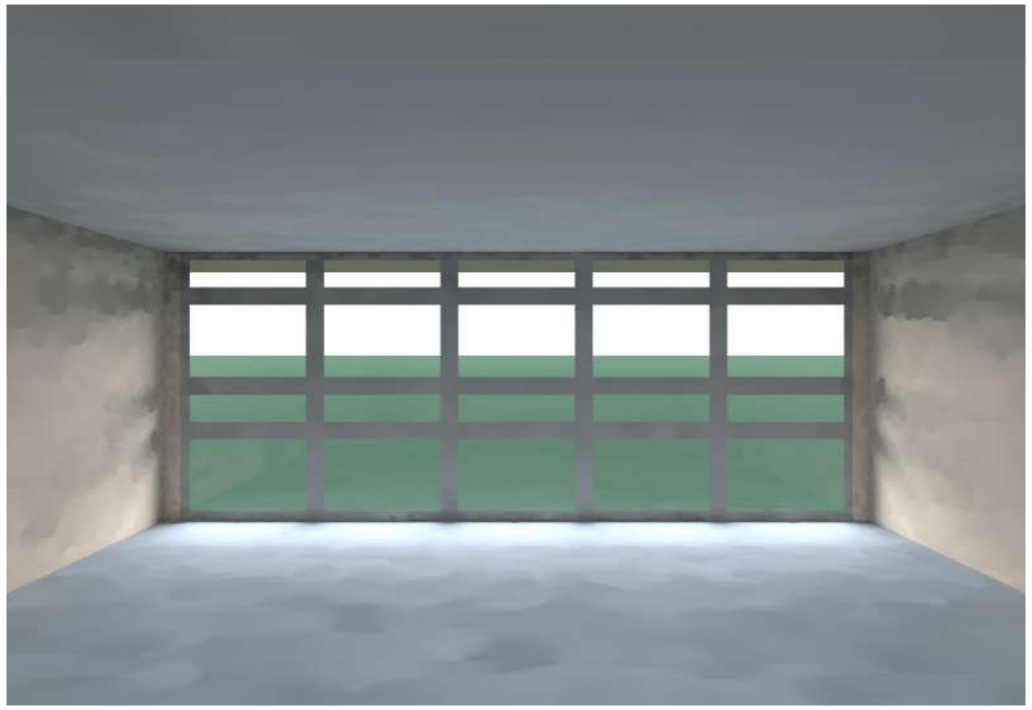


Carbon dioxide:



3.1 RESULTS – HALF LENGTH SOLAR SHADING

10 th. August. 12:00pm



10 th. March. 12:00pm

Internal perspective Luminance view

Daylighting Analysis

Average daylight factor : 3.1%

The average daylight factor for this building with full length solar shading is 3.1% , this result meets the standard requirement for daylighting and is quite similar to that of the full-length shading option. This also means that good daylight is achieved and reduces the need of artificial lighting during the brighter periods of the day.

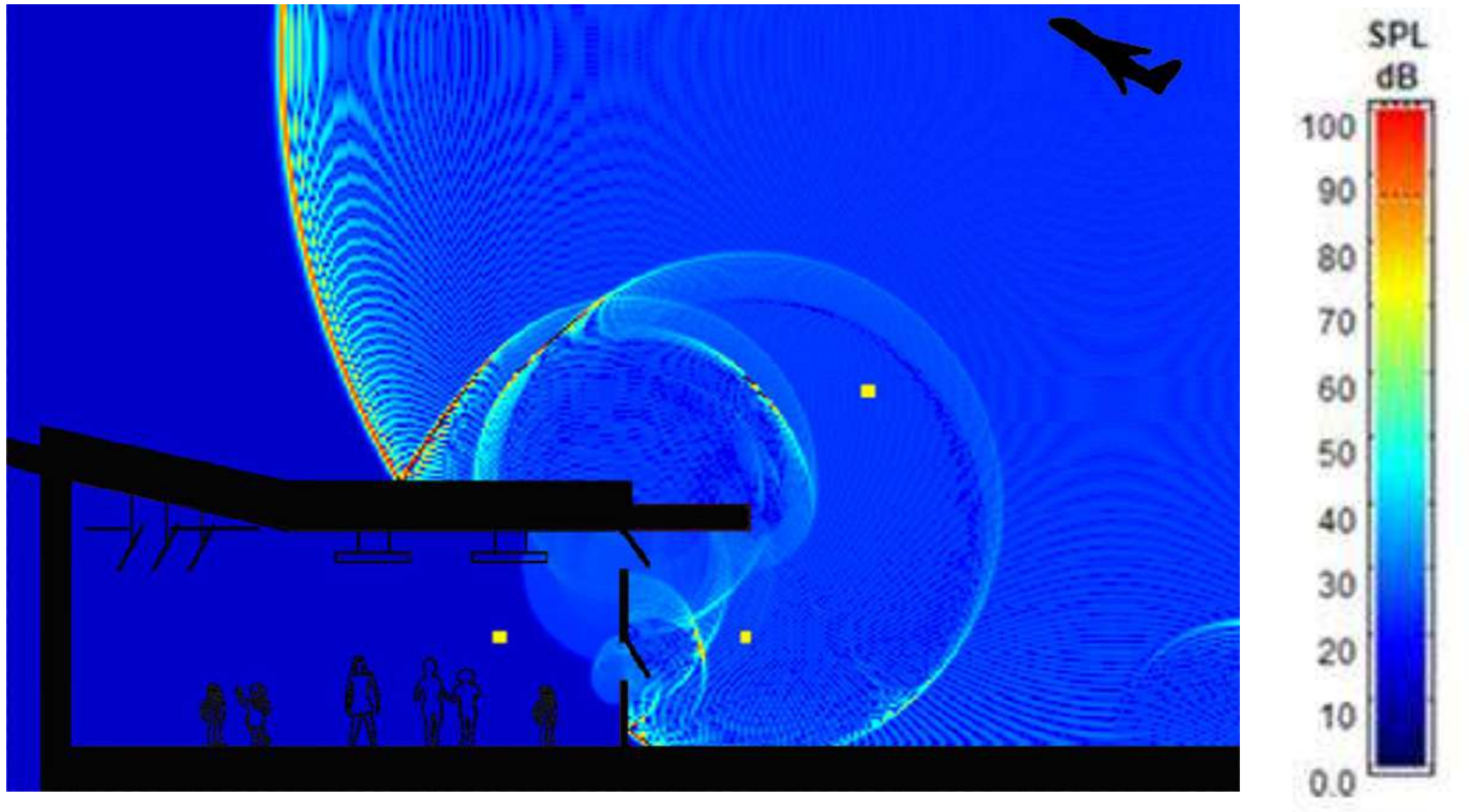
3.0 RESULTS – HALF LENGTH SOLAR SHADING

The images across show the FDTD model outputs for half-length shading, with images of sound propagation across the façade.

As per the full length shading option, noise break-in predictions have been compared to the no-shading option. This is found to be 2dB better than the no-shading option, while -3dB lower than the full-length shading option.

Façade Design	Noise Level Difference Across Façade Dw	Relative Difference of Façade Performance
Half Shading	24 dB	+2 dB

Table 3: Acoustics performance for half length solar shading



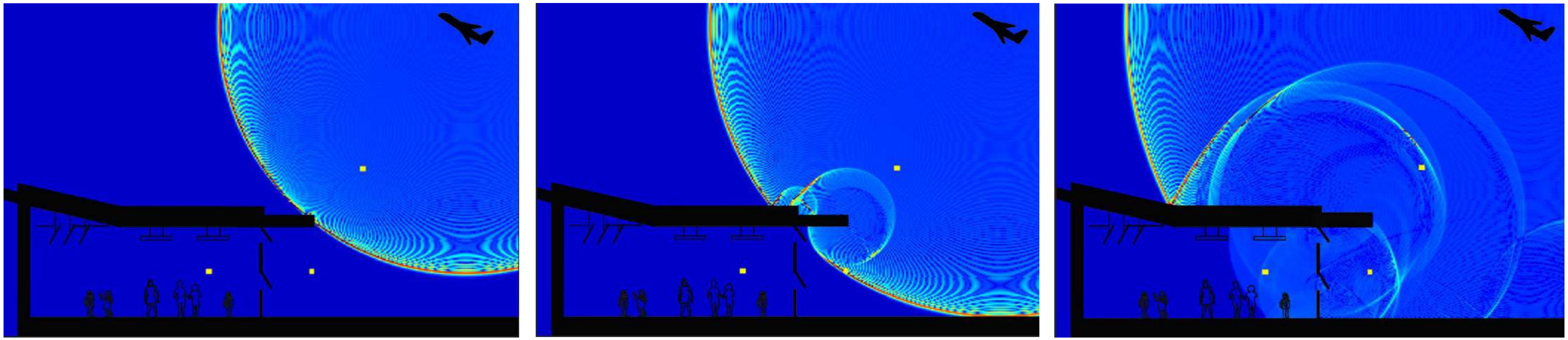
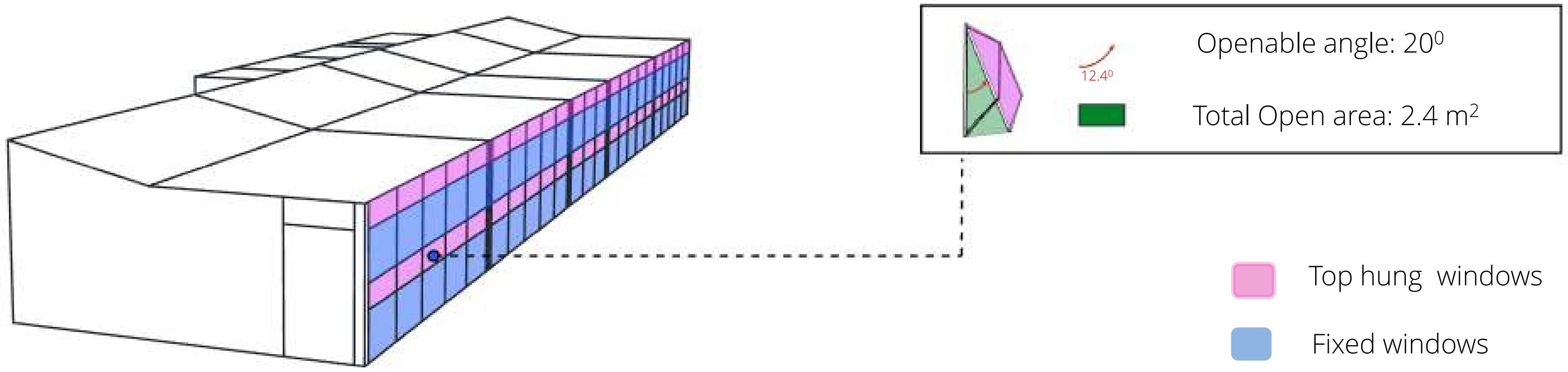
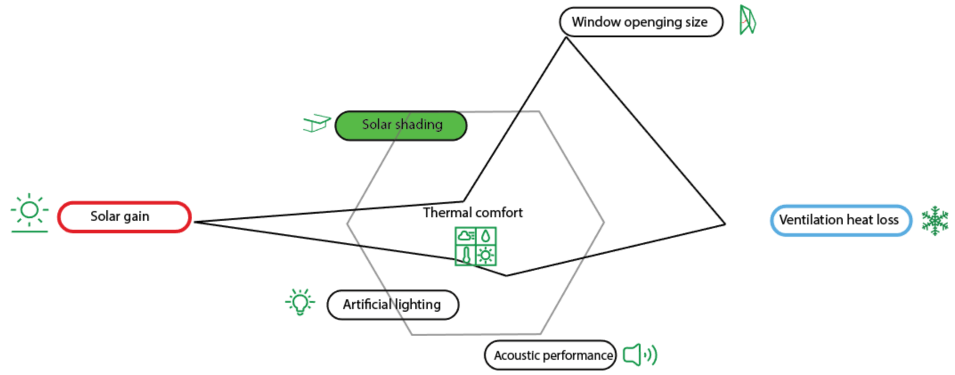


Figure 10. Acoustics performance visualisation for half length solar shading

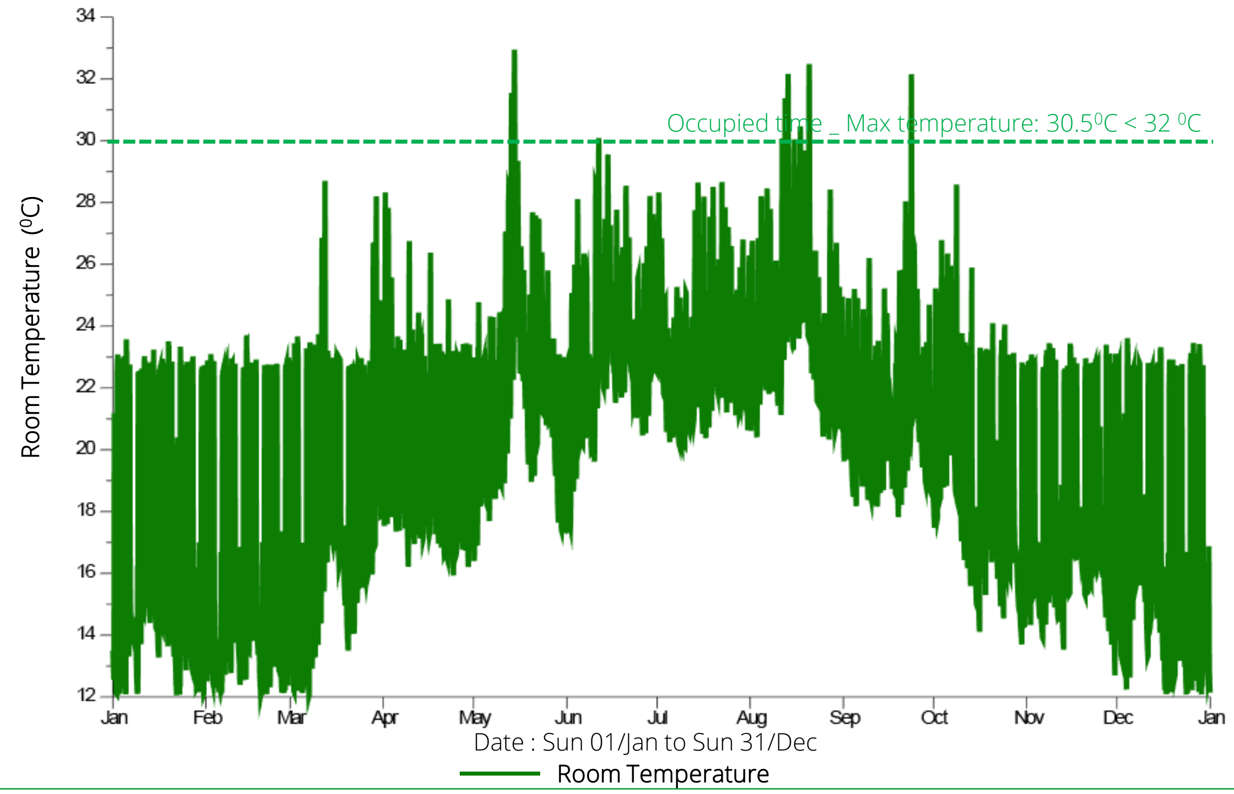
3.2 RESULTS – WITHOUT SOLAR SHADING

In order to achieve the thermal comfort for this building without solar shading, the required total open area will be 2.4 m² . The following figures show the modelling results : room temperature (max : 30.5⁰C) , carbon dioxide concentration (consistently below 1500ppm) and average daylight factor (6.4 %). It should be noted that the peak temperatures shown below are achieved during unoccupied time, where the maximum occupied temperature is 30.5ºC.

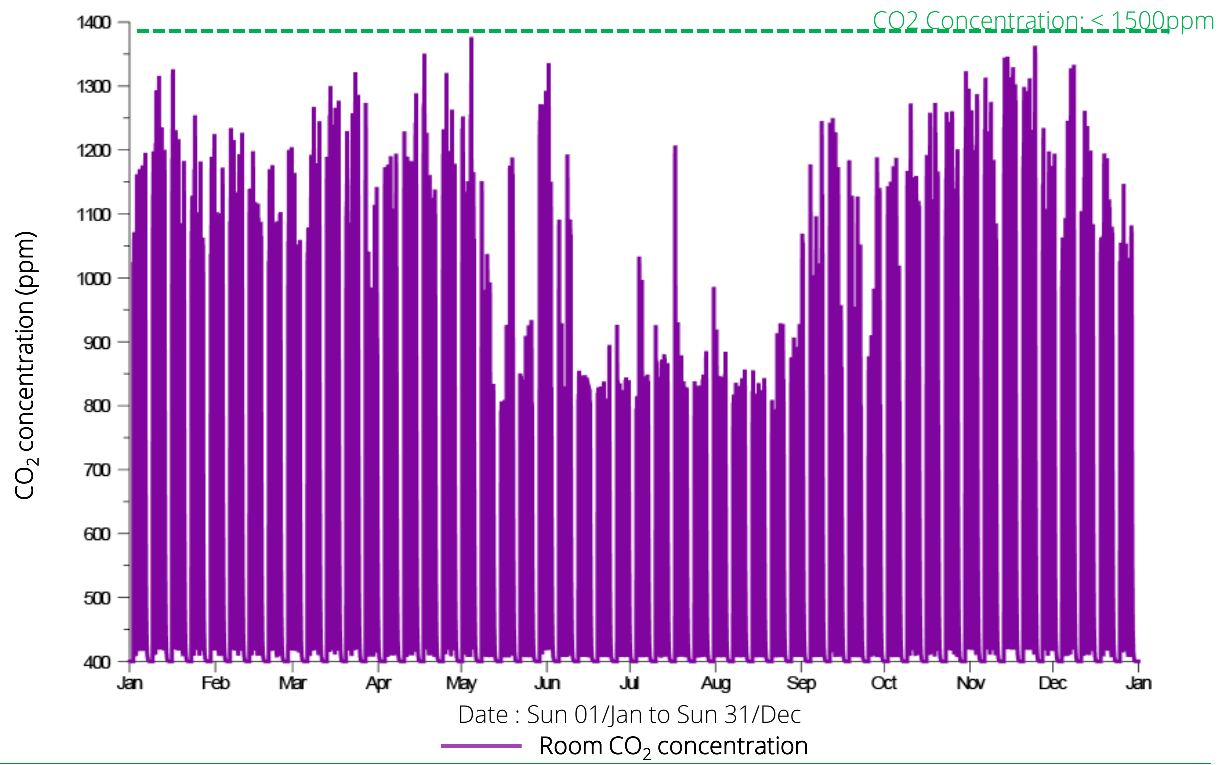




Room temperature:



Carbon dioxide:



3.2 RESULTS – WITHOUT SOLAR SHADING

10 th. August. 12:00pm

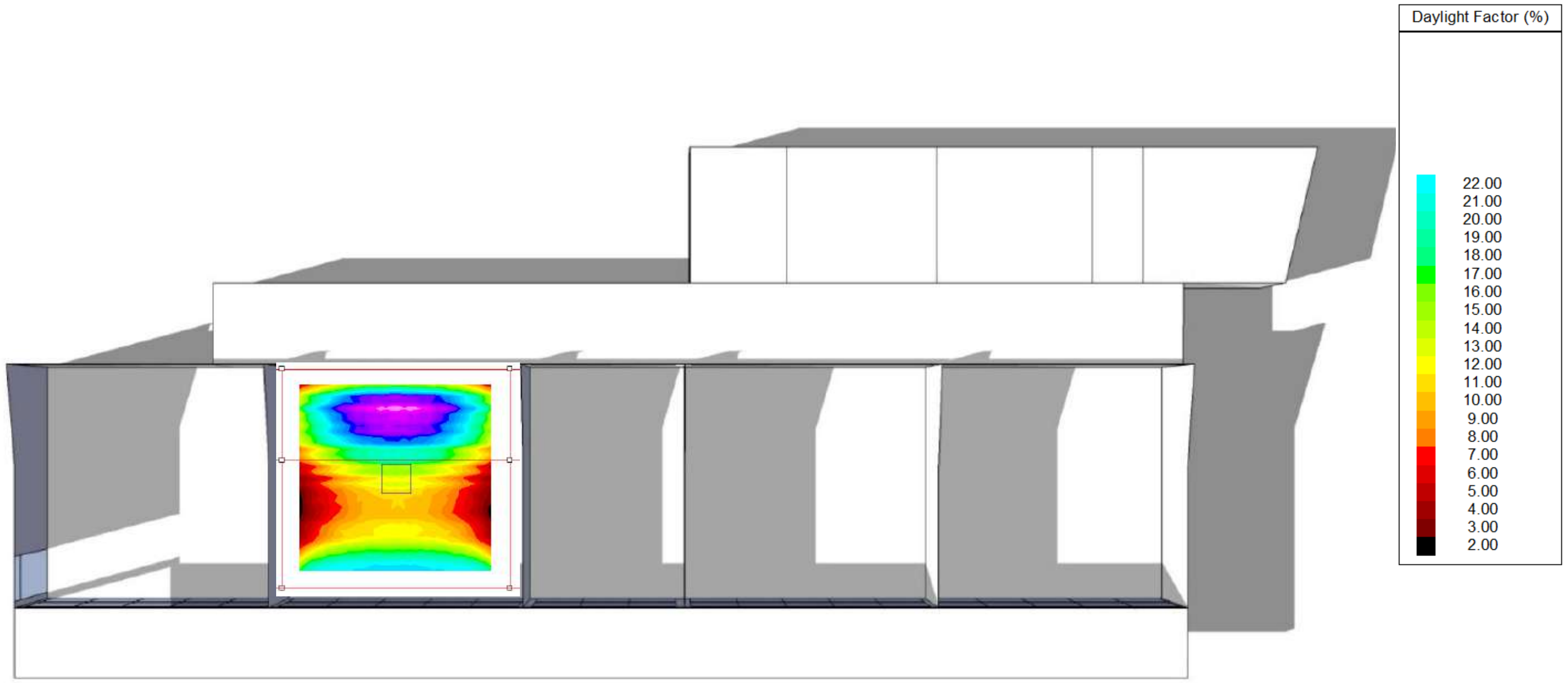
10 th. March. 12:00pm

Internal perspective Luminance view

Daylighting Analysis

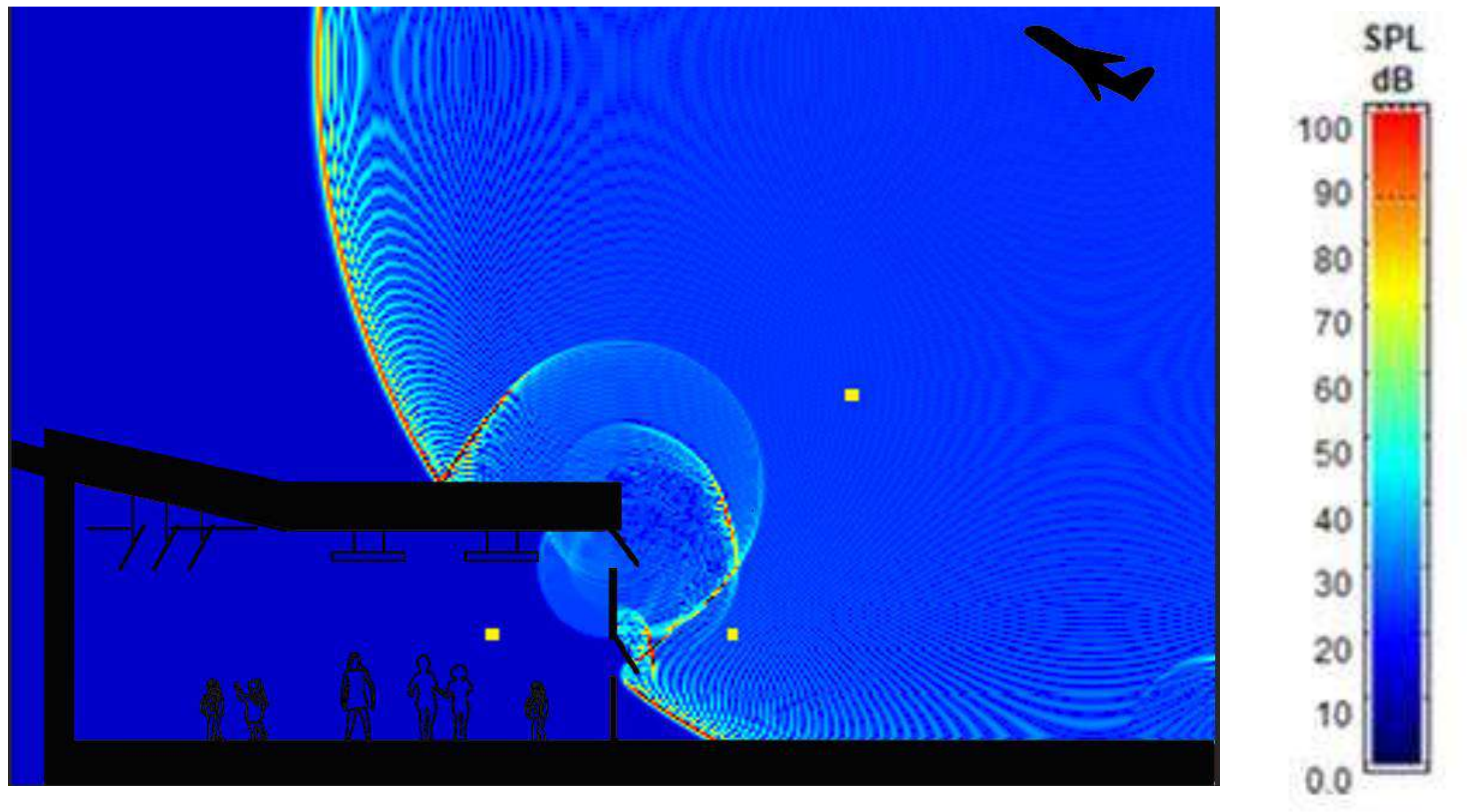
Average daylight factor : 6.4%

The average daylight factor for this building with full length solar shading is 6.4% , this result exceeds the standard requirement for daylighting and shows that this is risk of excessive glare within the classroom. The large amount of daylight provided will reduce the energy requirements for artificial lighting, however this may be offset by the need to use internal blinds for the majority of the day.



3.3 RESULTS – WITHOUT SOLAR SHADING

The images across show the FDTD modelling for the no-shading option. This is considered to be what is 'typical' for a standard classroom façade and will therefore be used to provide a comparison of the benefits of the previous shading options.



Façade Design	Noise Level Difference Across Façade Dw	Relative Difference of Façade Performance
No Shading	22 dB	-

Table 4: Acoustics performance for no solar shading

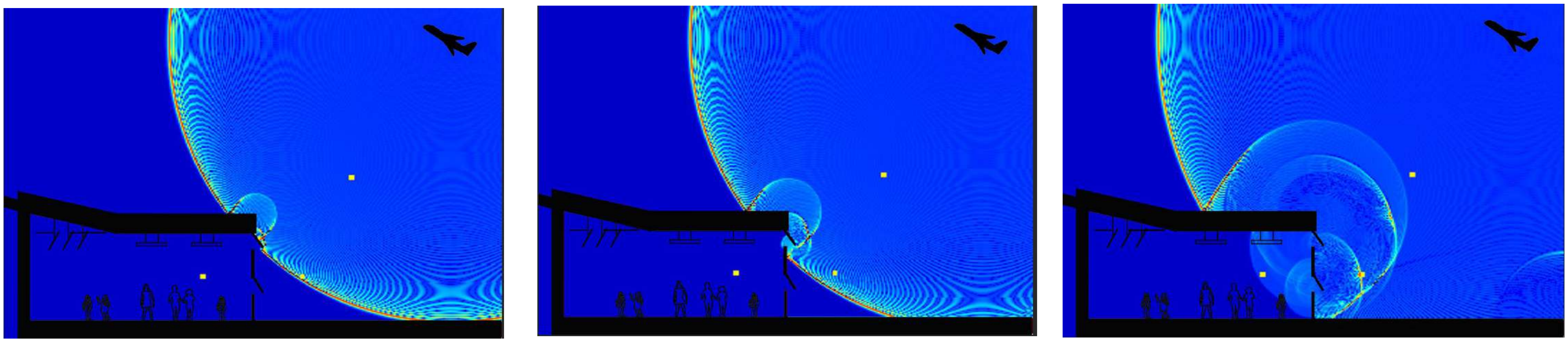
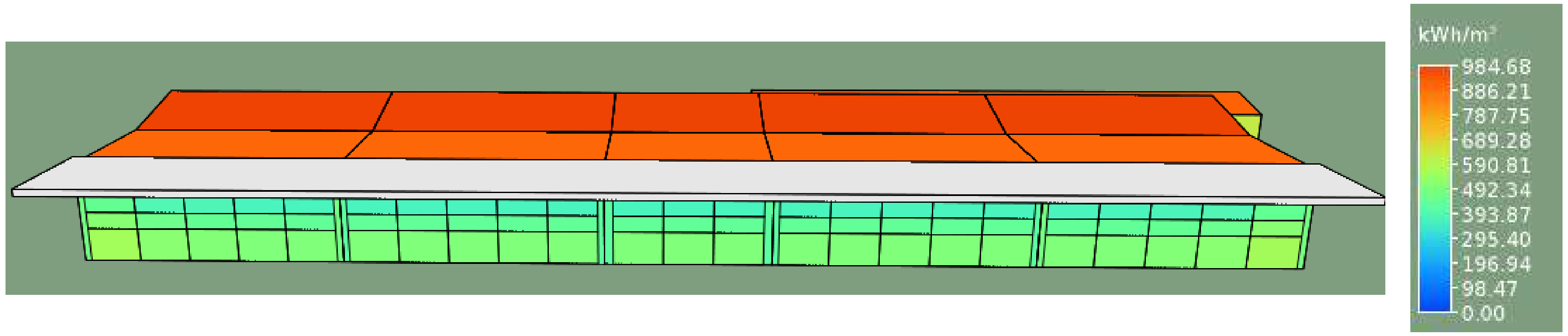


Figure 11. Acoustics performance visualisation for no solar shading

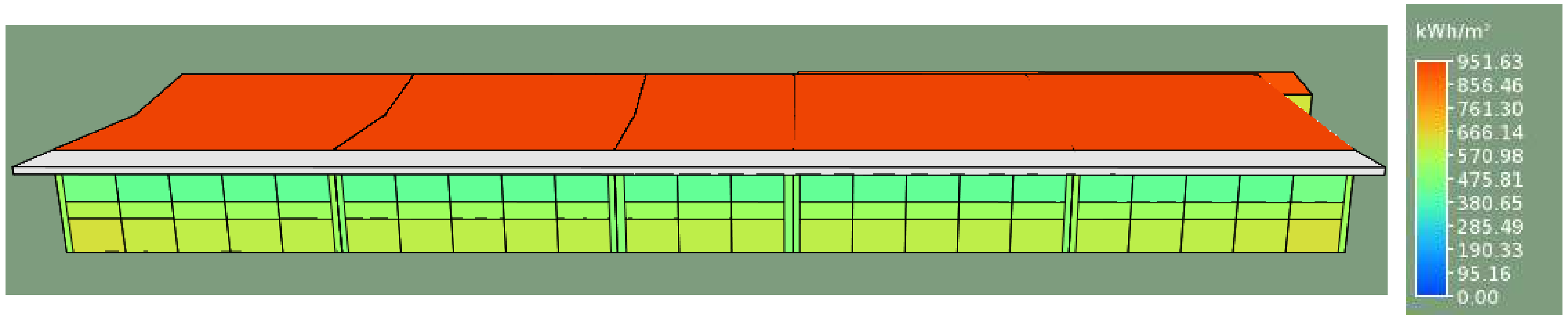
4.0 SHADING COMPARISONS

The images below show the difference between the three option in regards to daylight in each room and overall solar exposure. The daylight visualisations show some increase in daylight as the shading increase, while the exposure on the windows increase by almost 200%.

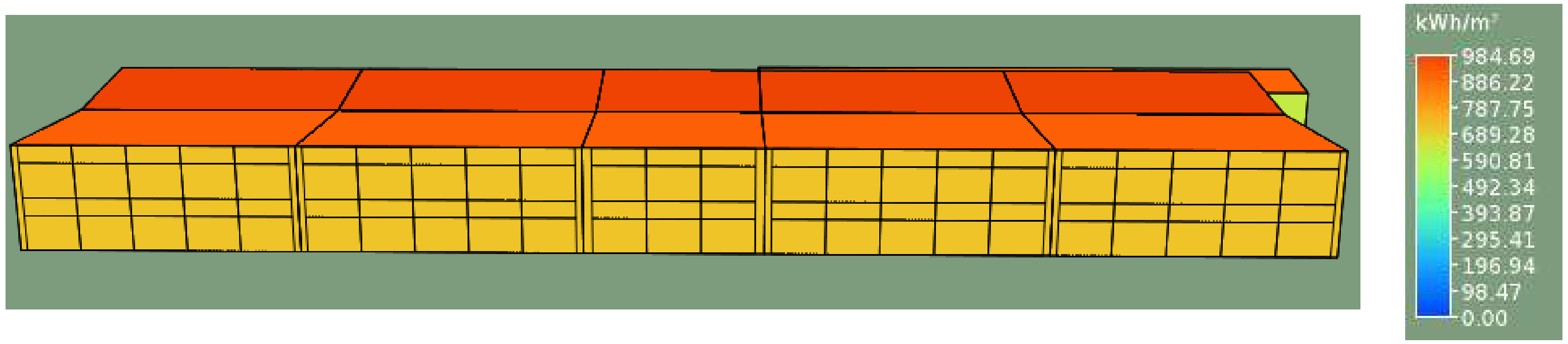
Full length solar shading



Half length solar shading



Without solar shading

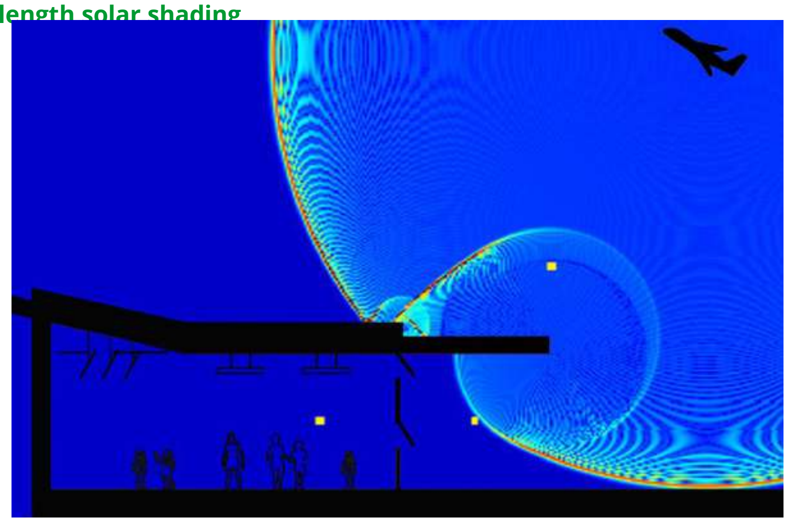


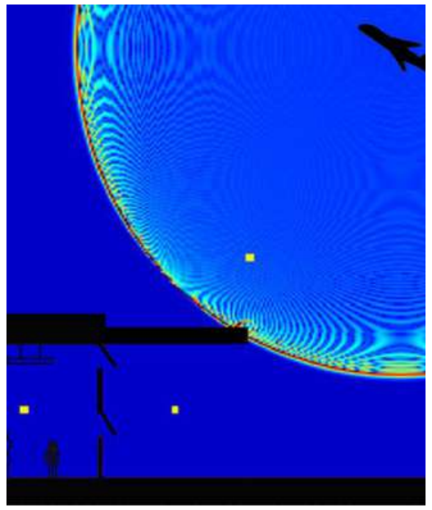
Internal perspective Luminance view

Solar exposure for south façade

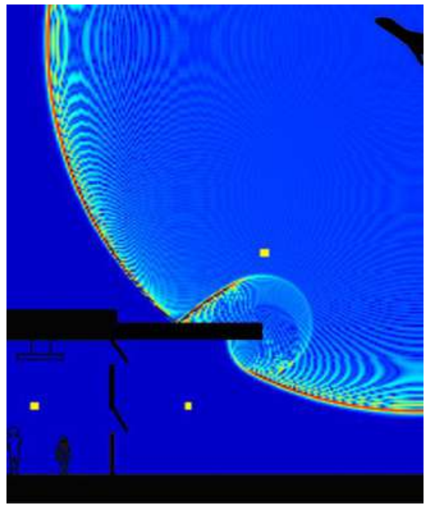
4.0 ACOUSTICS COMPARISON

Full length solar shading

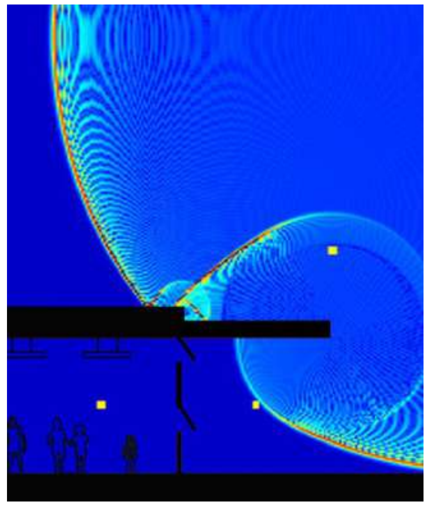




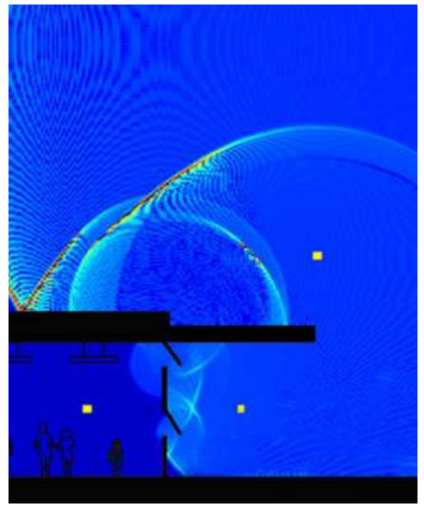
Full shading 1



Full shading 2

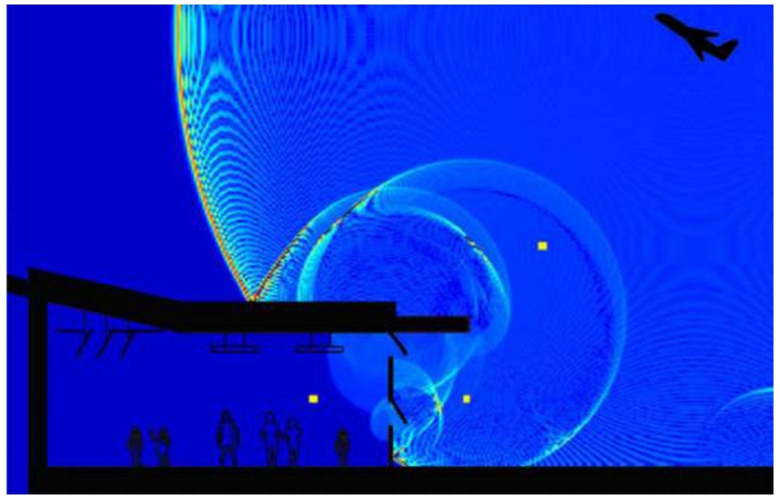


Full shading 3

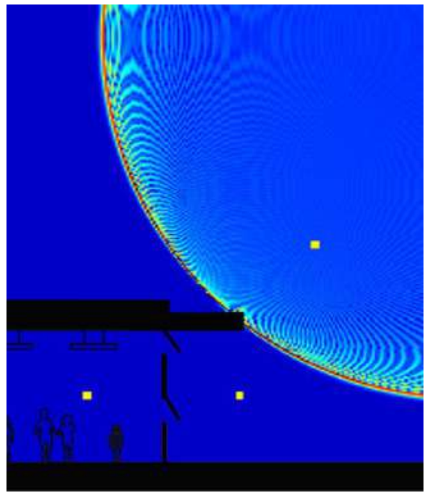


Full shading 4

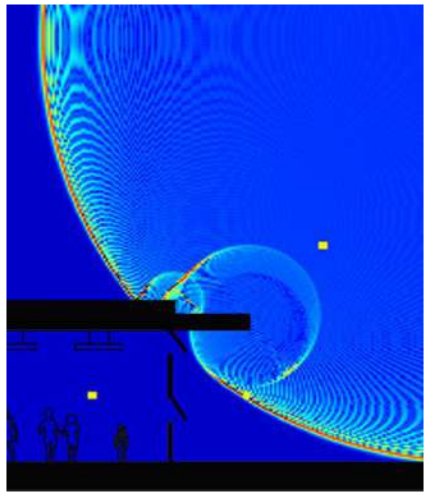
Half length solar shading



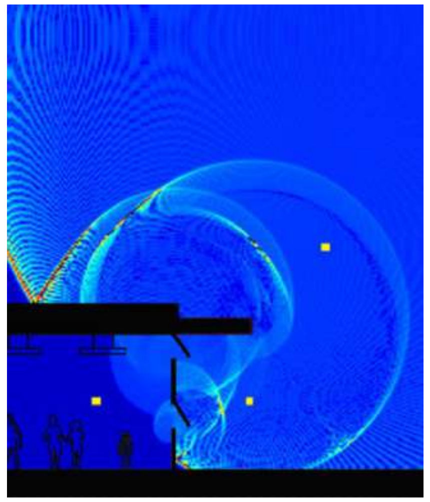
Half shading 3



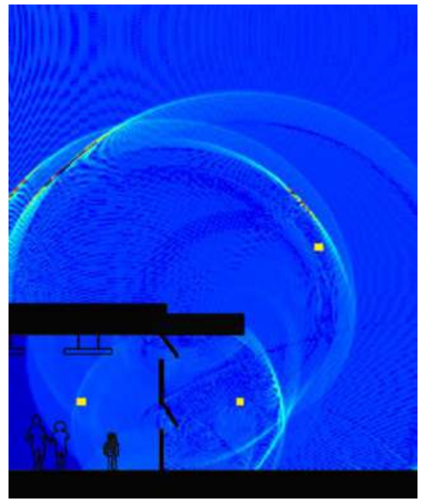
Half shading 1



Half shading 2

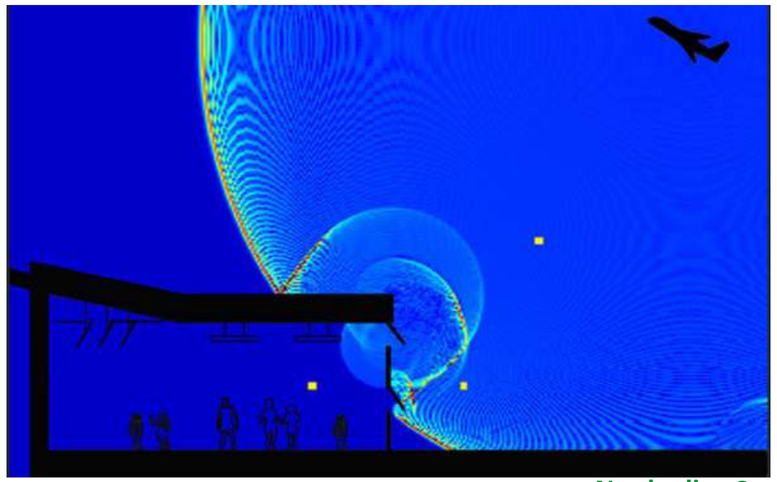


Half shading 3

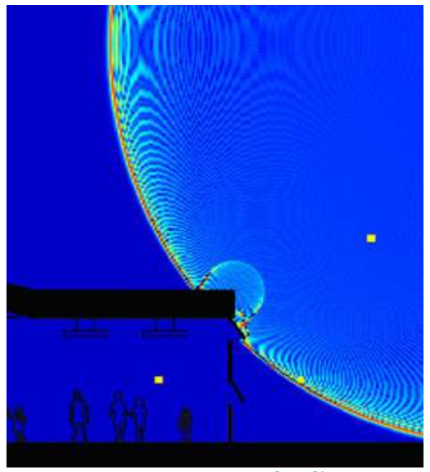


Half shading 4

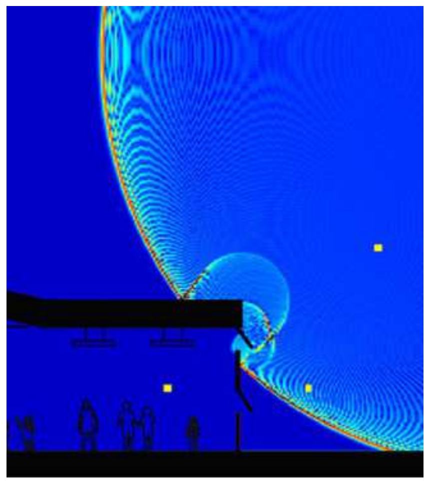
Without solar shading



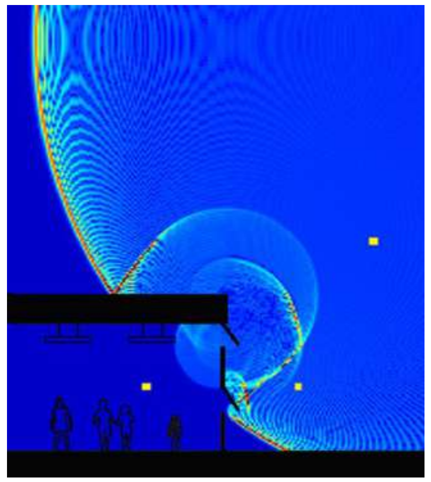
No shading 3



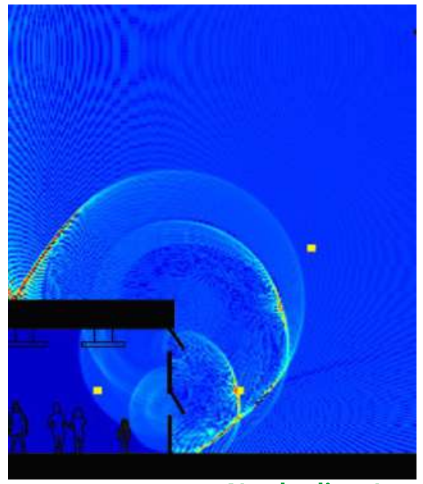
No shading 1



No shading 2



No shading 3

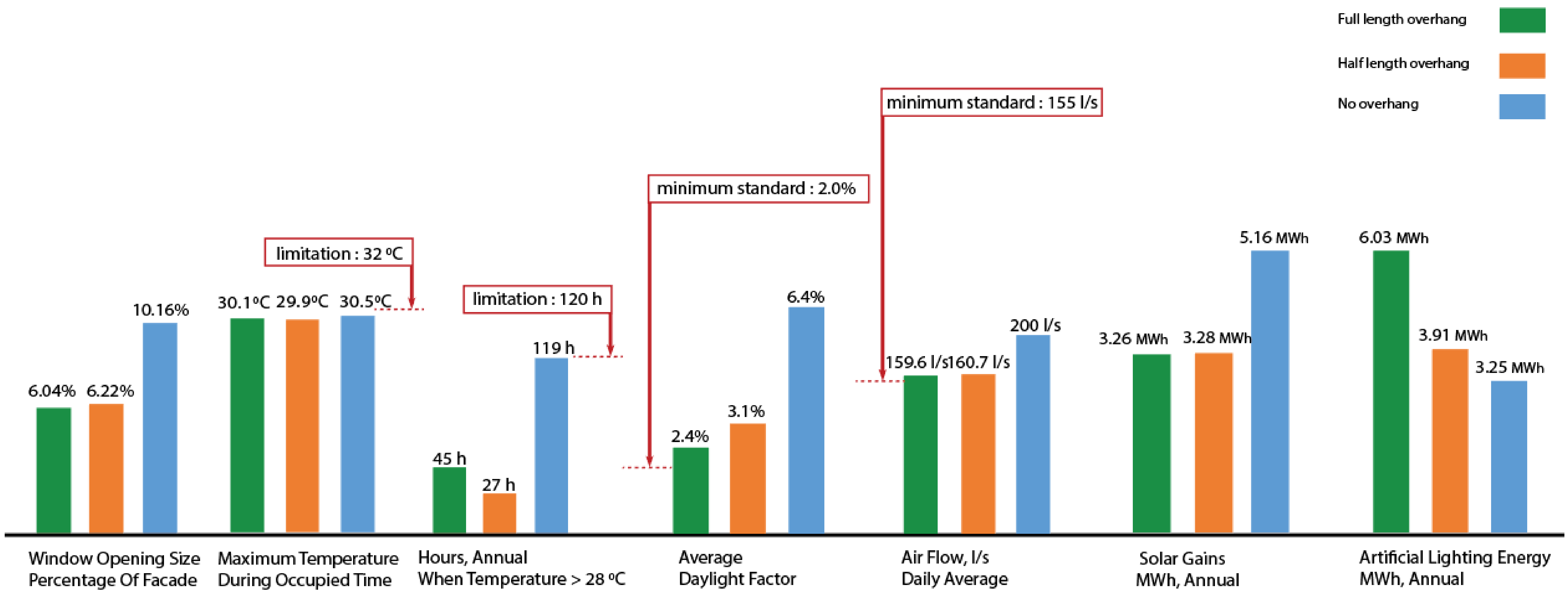


No shading 4

4.0 OVERALL COMPARISON

	Window Openings Size Percentage of Façade	CO_2 Concentration	Occupied Time Maximum Temperature	Hours when Temperature > 28Cº	Daylighting Factor	Air Flow, l/s Daily Average	Solar Gains	Artificial Lighting Energy	Relative Noise Level Difference
Requirement		< 1500 ppm	32	120	> 2%	155 (class)			
Full length overhung	6.04%	**< 1500 ppm**	**30.1**	**45**	**2.4%**	**159.6**	**3.26 MWh**	**6.03 MWh**	**+5dB**
Half length overhung	6.22%	**< 1500 ppm**	**29.9**	**27**	**3.1%**	**160.7**	**3.28 MWh**	**3.91 MWh**	**+2dB**
No shading	10.16%	**< 1500 ppm**	**30.5**	**119**	**6.4%**	**200**	**5.16MWh**	**3.25MWh**	**0dB**

Table 5: Modelling results for three solar shading proposals



5.0 CONCLUSIONS

From the comparisons shown overleaf, both the full-length and no-shading option have large flaws, such as large energy loads for lighting, or excessive daylight and solar gains.

The sole benefit of the large shading option is that the acoustic performance is 3dB, however if there it is found that this extra level difference is not a requirement then it can be seen as an unnecessary feature.

The benefit of having no shading canopy is that the artificial lighting loads are very low, however this may need treated with caution, as blinds will likely need to be used to stop glare, and thereby will increase the need for artificial lighting.

As such, the mid-length shading canopy option is seen to be most suitable, as this balances certain aspects of the design well, particularly in regards to daylight, acoustics and overheating. Further analysis, however, will enable us to further define the most efficient shading length and find the 'sweet spot' that gives the most efficient performance.