CUNDALL

Information paper – 19

Façade modelling – daylight and thermal performance

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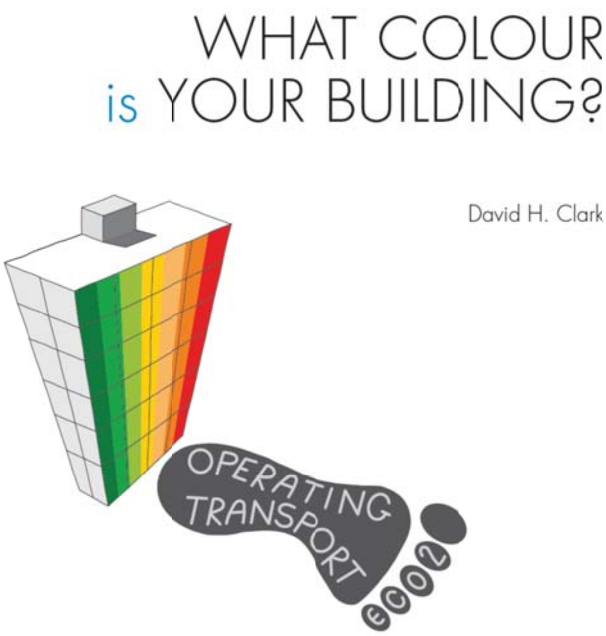
A paper referenced in the book:



Issue 1.0: 29 July 2013

This information paper is one of a series of papers written during the preparation of the book **What Colour is Your Building?** (www.whatcolourisyourbuilding.com). The papers do not form part of the book and have not been peer reviewed. They provide further technical detail, analysis and information to support statements made in the book. All of the papers can be downloaded from www.wholecarbonfootprint.com.

Façade modelling – daylight and thermal performance

This information paper describes the inputs, methodology and outputs for the façade modelling summarised in Section H3.10 in Appendix H. The purpose was to show:

- The thermal and daylight performance of nine different glazing and shading configurations.
- The effect of blinds on thermal performance.
- The difference between daylight factor and useful daylight index.
- When natural ventilation is possible.

1. INPUTS AND ASSUMPTIONS

The building modelled is in central London with a floor plan of 15 m by 50 m, a floor to floor height of 3.6 m and a ceiling height of 2.7 m. The end walls have no glazing and the daylight and comfort modelling results for the different façade options are for a central slice through the building. Figure 1 shows the thermal model (using IES software) with nine different façade options and Figure 2 shows the dimensions of each façade option.

No overshadowing from adjacent buildings is assumed. This could reduce solar gain and daylight levels, and would consequently alter the results discussed in this paper.

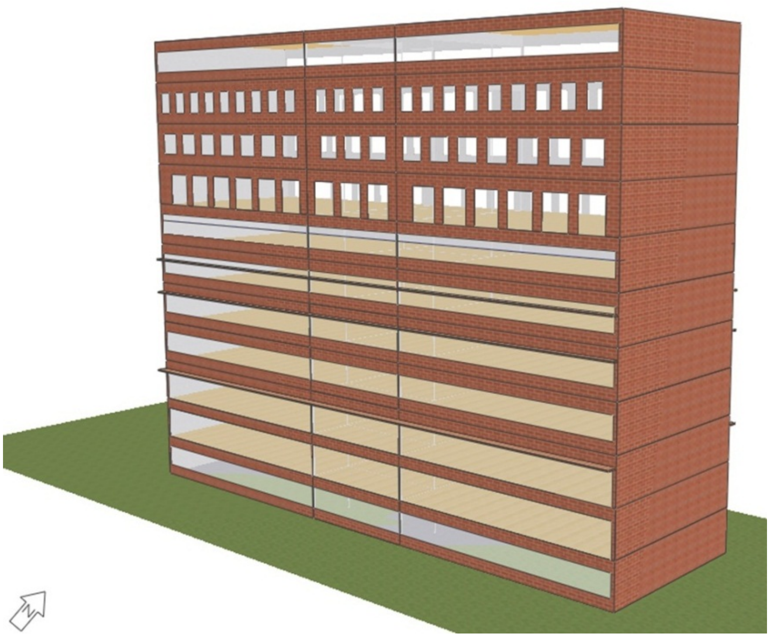
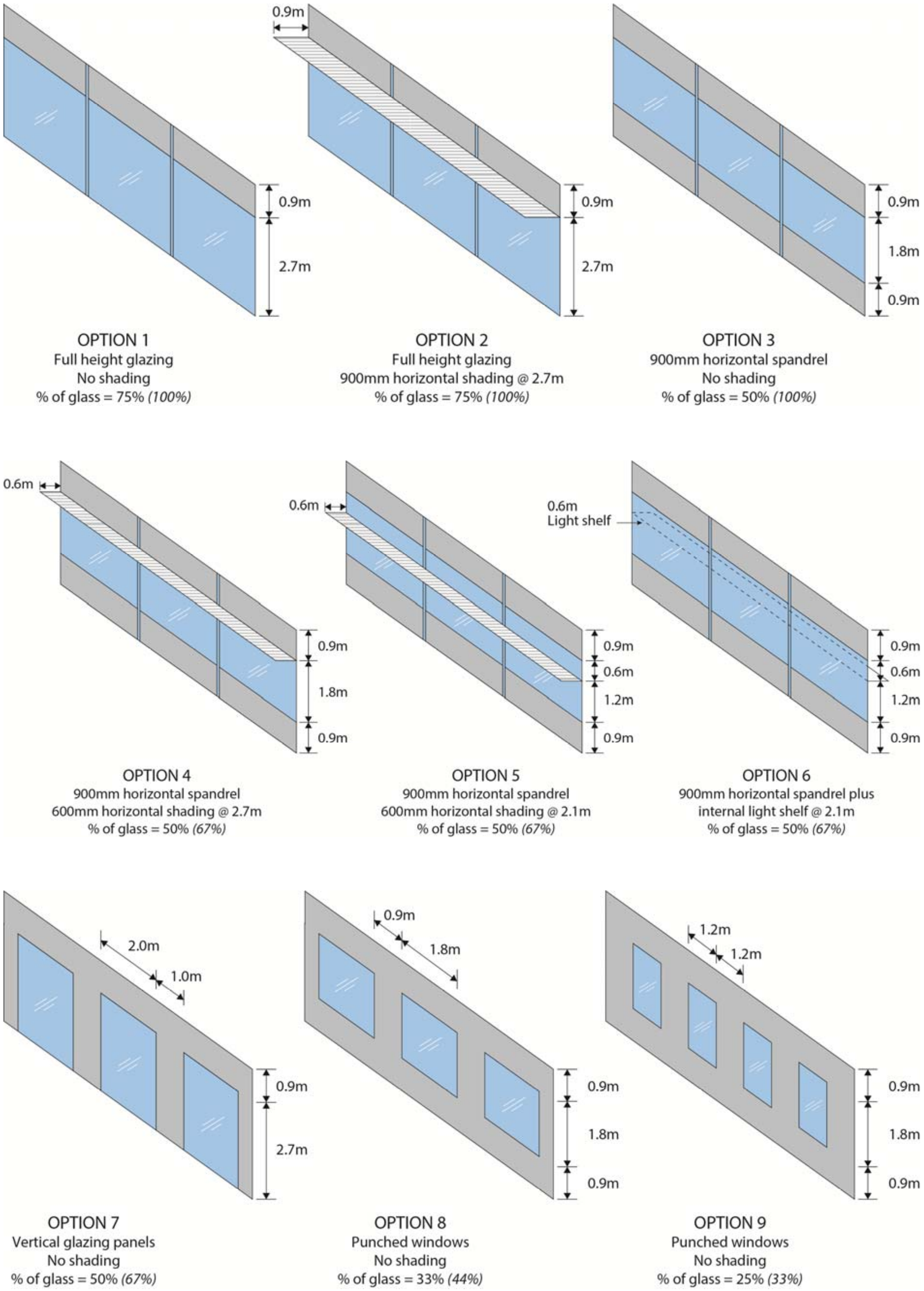


Fig 1 Thermal model used for comfort analysis



The percentage of glass is based on the floor to floor façade area. The percentage of glass in brackets is based on the floor to ceiling façade area (i.e. the occupied zone).

Fig 2 Dimensions of façade options 1 to 9

Table 1 shows the performance criteria for the façade elements and Table 2 shows the assumptions for internal heat loads and reflectance.

Parameter	Value (no blinds)	Value (with blinds)
SHGC	0.33	0.28
Visible light transmission	0.61	0.24
U-value of glazing system	1.8 W/m^2.k	
U-value of wall elements	1.8 W/m^2.k	
Air tightness	5 m^3/m^2.hr	

Table 1 **Façade performance criteria**

	Assumption
Internal heat loads	
Occupancy	1 person per 10 m^2
Equipment	15 W/m^2
Lighting	10 W/m^2
Internal reflectance	
Ceiling	0.75
Wall	0.6
Floor	0.25
Light shelf	0.9

Table 2 **Internal heat loads and surface reflectance**

To calculate the operative temperatures without air conditioning it was assumed that an effective ventilation open area equivalent to 2.5% was provided to opposite facades, split equally between high and low level openings on each façade. The zone for perimeter heat load calculations was modelled as 4m wide.

The building was modelled on an east-west axis, and then again on a north-south axis to obtain the results for north, south, east and west facing facades. No external shading was assumed on the north façade.

2. ANALYSIS & RESULTS

Thermal modelling

The IES modelling, undertaken by Cundall's Genesys team, was used to calculate:

- Compliance with Criteria 3 of Part L 2010.
- Peak cooling demand (W/m2) in the 4 m wide perimeter zone with a set-point of 23°C for an air conditioned building.
- Peak operative temperature (°C) in the 4 m wide perimeter zone assuming natural ventilation with 2.5% open area on opposite facades.
- No. of hours per annum that the operative temperature exceeds 26°C, 28°C and 30°C with natural ventilation.

The full outputs of the analysis are shown in Table 3. Figure 3 summarises the results which all show a consistent trend – option 1 has higher operative temperatures and cooling loads (40°C and 119 W/m2) than option 9 (32°C and 55 W/m2).

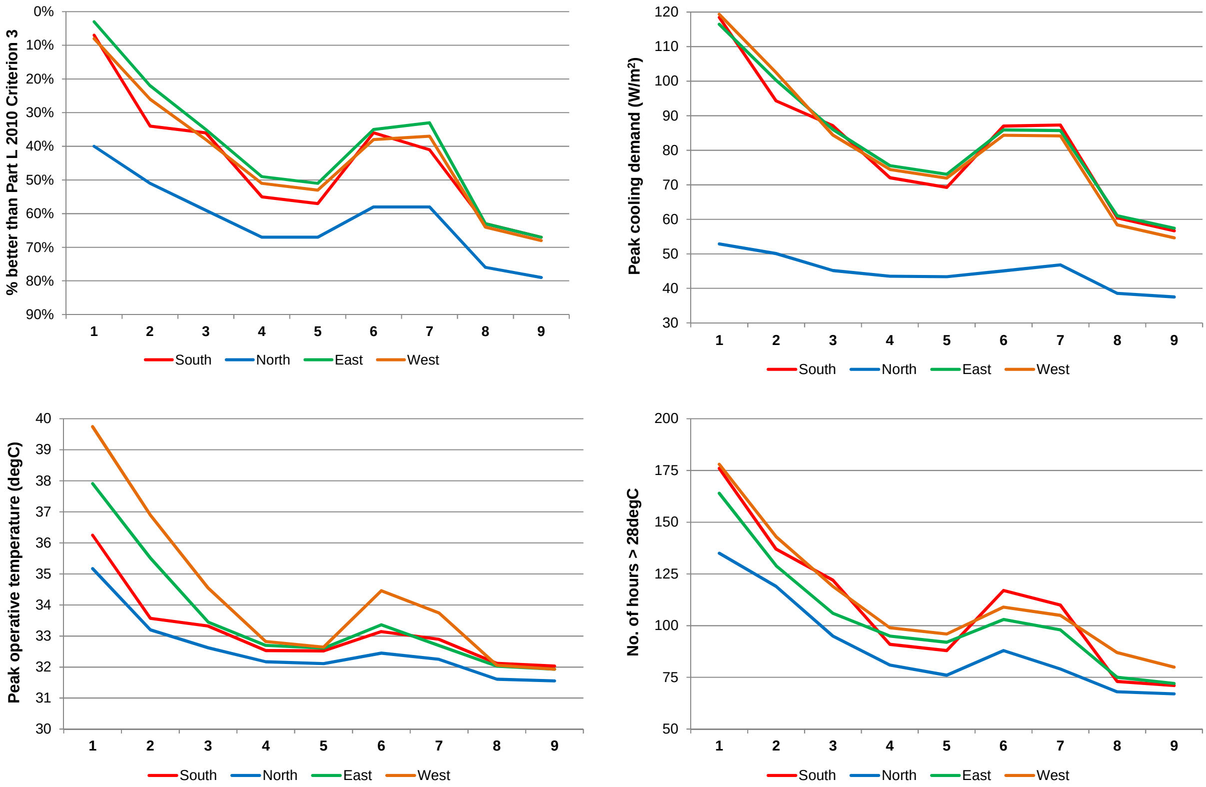


Fig 3 Thermal comfort indicators for different façade options and orientations

Facade	% pass Criterion 3 of Part L				Peak cooling demand in perimeter zone with set point 23°C (W/m²)				Peak operative temperature in perimeter zone (°C)			
	South	North	East	West	South	North	East	West	South	North	East	West
1	7%	40%	3%	8%	118.4	52.9	116.4	119.3	36.3	35.2	37.9	39.7
2	34%	51%	22%	26%	94.3	50.1	100.2	102.5	33.6	33.2	35.5	36.9
3	36%	59%	35%	38%	87.1	45.2	86.0	84.4	33.3	32.6	33.5	34.6
4	55%	67%	49%	51%	72.0	43.5	75.5	74.4	32.5	32.2	32.7	32.8
5	57%	67%	51%	53%	69.2	43.4	73.0	71.9	32.5	32.1	32.6	32.6
6	36%	58%	35%	38%	87.0	45.1	85.9	84.3	33.1	32.5	33.4	34.5
7	41%	58%	33%	37%	87.3	46.8	85.7	84.1	32.9	32.3	32.7	33.7
8	63%	76%	63%	64%	60.4	38.6	61.0	58.4	32.1	31.6	32.0	32.1
9	67%	79%	67%	68%	56.7	37.5	57.4	54.6	32.0	31.6	31.9	31.9

Facade	No. of hours that operative temperature exceeds 26°C				No. of hours that operative temperature exceeds 28°C			
	South	North	East	West	South	North	East	West
1	344	283	391	340	176	135	164	178
2	292	262	307	293	137	119	129	143
3	280	239	266	260	122	95	106	119
4	235	220	238	233	91	81	95	99
5	229	217	230	227	88	76	92	96
6	266	228	257	253	117	88	103	109
7	245	219	248	239	110	79	98	105
8	213	190	201	198	73	68	75	87
9	210	192	198	195	71	67	72	80

Table 3 Thermal modelling results – no blinds

The model was also run with blinds down. This showed a reduction in the peak cooling demand to the perimeter zone of the south, east and west facades of between 5% (option 9) and 10% (option 1).

For the building to work with natural ventilation it is essential to keep the internal and solar gains to a minimum. The modelling showed that the hours that 28°C would be exceeded each year in this building is too high for all options. However, if the internal loads are reduced and thermal mass introduced into the space with night purge (e.g. an exposed concrete soffit) then it is very likely that façade options 8 and 9 could be made to work satisfactorily – their peak cooling load to the perimeter is currently around 60W/m² and would need to be reduced to around 40W/m² to be cooled naturally. Alternatively, a mixed mode system could be utilised, which only operates during the peak cooling periods, with the rest of the cooling period being naturally ventilated.

Daylight modelling

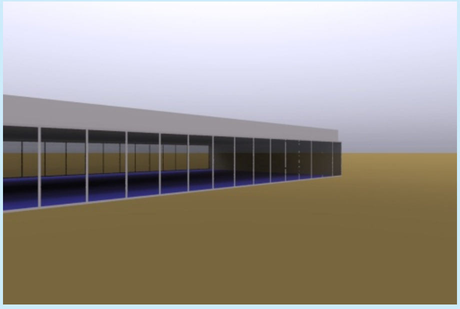
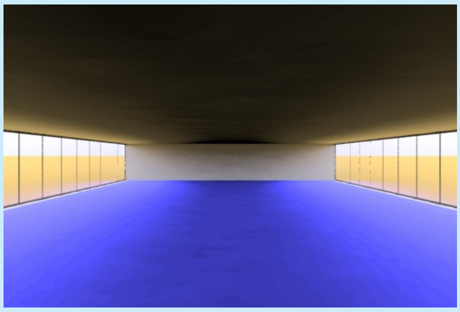
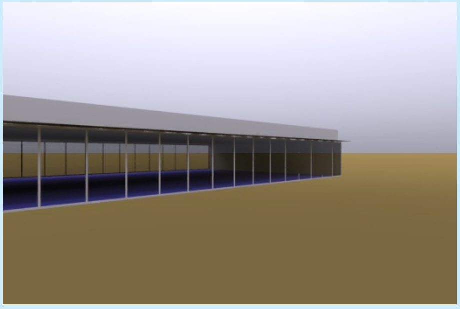
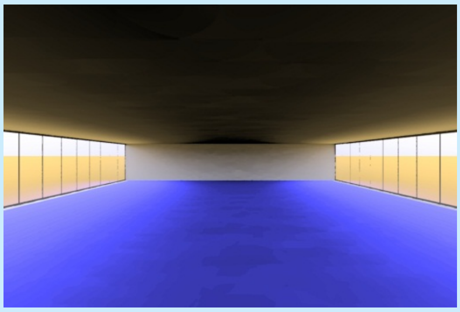
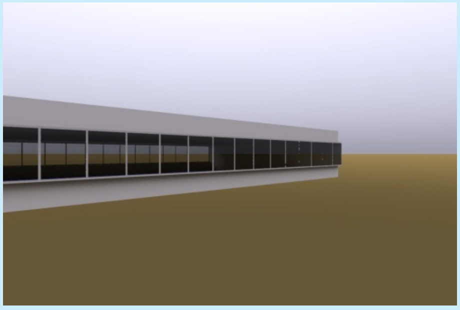
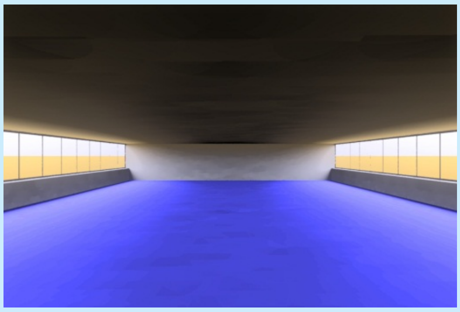
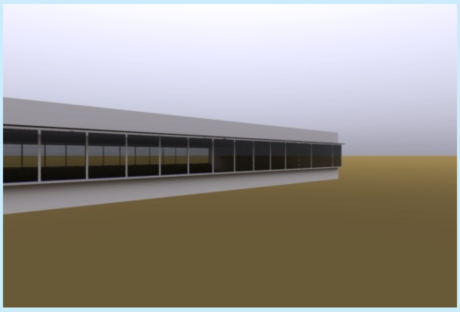
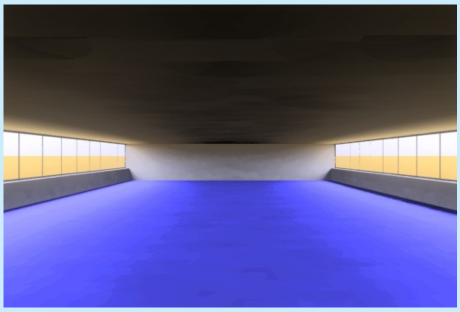
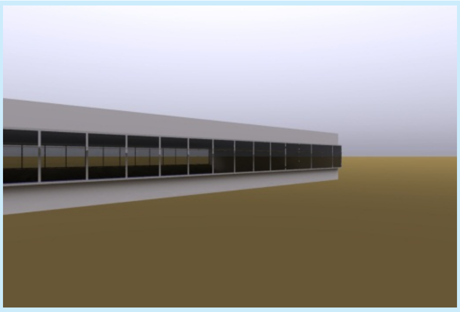
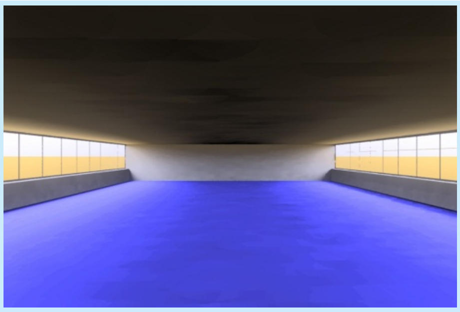
The daylight was modelled using Radiance software by Cundall's Light4 team and was used to calculate daylight factors and the useful daylight index (UDI). *Information Paper 36 – Useful daylight index* provides further details on the UDI. The daylight factors were based on a uniform overcast sky and the UDI was calculated using climate based daylight modelling, which considers the position and intensity of the sun throughout the year.

For the daylight factor no blinds were assumed. The UDI range was set at 100 to 2000 lux (i.e. daylight below 100 lux is insufficient and daylight above 2000 lux was assumed too bright resulting in blinds being pulled down). The outputs of the analysis are summarised in Table 4. Images from the radiance model are shown in Table 5.

Facade	Average daylight factor (0m to 2m from façade)				Average daylight factor (2m to 4m from façade)				Average daylight factor (4m to 6m from façade)			
	South	North	East	West	South	North	East	West	South	North	East	West
1	11.7	10.6	10.6	10.6	4.9	4.5	4.0	4.0	2.8	2.8	2.5	2.5
2	7.6	10.5	7.0	7.0	3.8	4.4	3.2	3.2	2.5	2.8	2.1	2.1
3	10.5	9.5	9.5	9.5	4.1	3.7	3.3	3.3	2.2	2.2	1.9	2.0
4	7.6	9.5	6.9	6.9	3.4	3.7	2.8	2.8	2.0	2.2	1.7	1.7
5	8.4	9.5	7.6	7.7	3.8	3.7	3.0	3.0	2.1	2.2	1.8	1.8
6	8.4	9.5	7.5	7.6	3.5	3.7	2.8	2.8	2.1	2.2	1.8	1.8
7	7.4	6.7	6.7	6.7	3.1	2.8	2.5	2.5	1.8	1.8	1.5	1.5
8	6.7	6.0	7.0	7.0	2.6	2.3	2.3	2.3	1.4	1.4	1.3	1.3
9	4.4	3.9	4.0	4.0	1.7	1.5	1.4	1.3	0.9	0.9	0.8	0.8

Façade	% of 6m zone with useful daylight (100-2000Lux)				% of floor plate with useful daylight (100-2000Lux)	
	South	North	East	West	North to South	East to West
1	52%	73%	65%	71%	66%	66%
2	60%	74%	72%	76%	69%	73%
3	57%	78%	69%	75%	70%	70%
4	63%	78%	74%	78%	72%	75%
5	61%	78%	72%	76%	71%	73%
6	61%	78%	73%	77%	72%	74%
7	65%	83%	75%	78%	75%	76%
8	67%	83%	74%	78%	76%	75%
9	72%	81%	76%	76%	76%	76%

Table 4 **Daylight modelling results**

Facade	External	Internal
1		
2		
3		
4		
5		

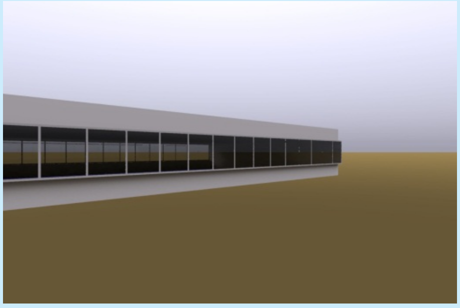
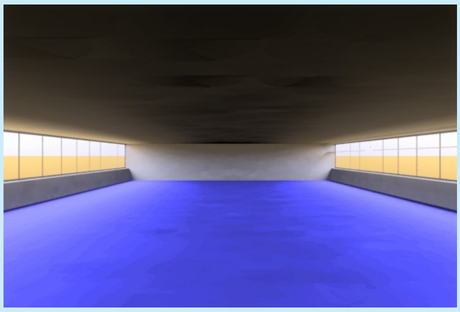
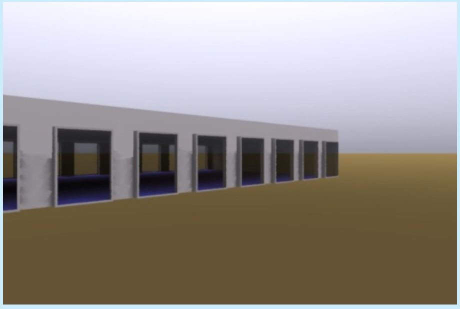
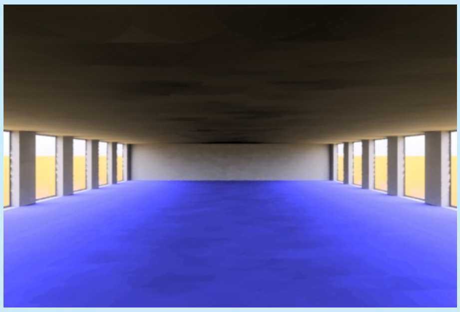
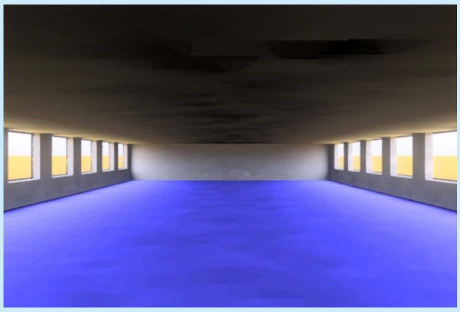
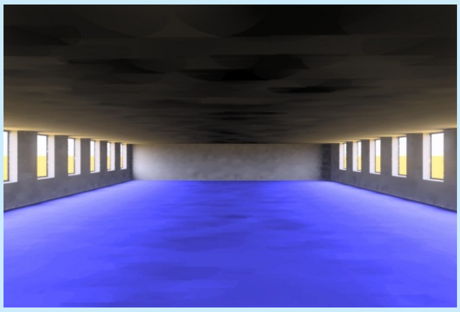
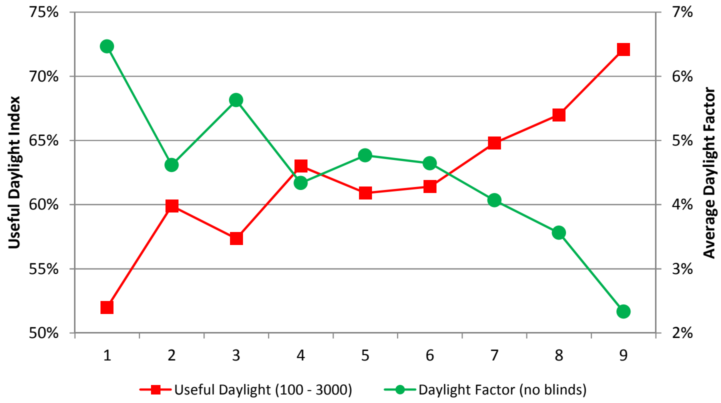
Facade	External	Internal
6		
7		
8		
9		

Table 5 **Images from daylight modelling**

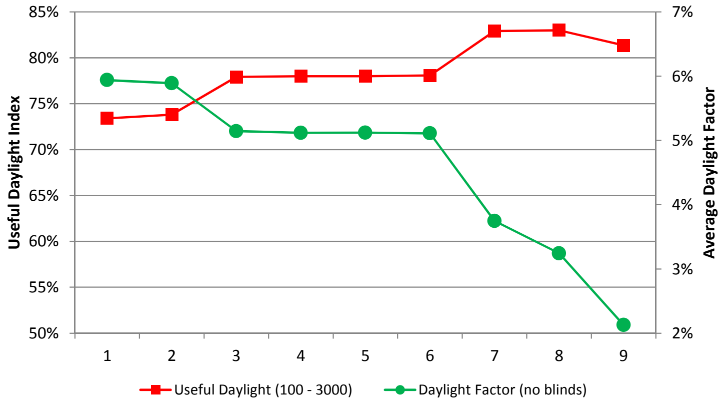
Figure 4 shows the difference in results for each façade for daylight performance using daylight factors and the useful daylight index (UDI). These charts were combined to produce Figure H.16 in Appendix H.

Option 1, with full height glazing, has the best daylight factor (scoring daylight points in BREEAM) but the worst useful daylight (because there is too much daylight). Conversely, option 9 with 33% glazed area to the wall area below ceiling level, has the worst daylight factor but the highest UDI. Putting lots of glass in buildings to provide better daylight is a flawed approach. Size isn't everything: it's not how big it is, it's how you use it.

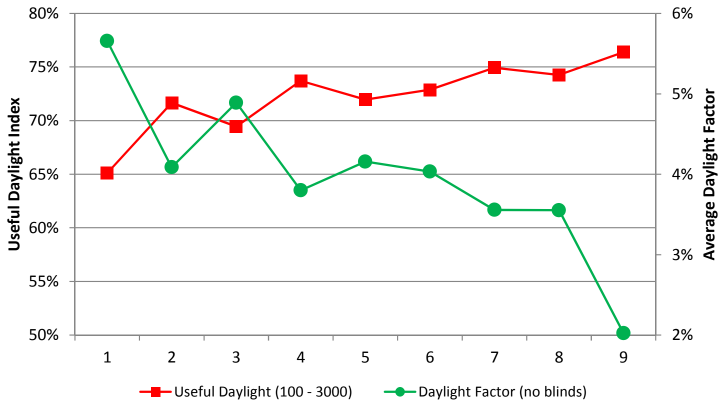
South



North



East



West

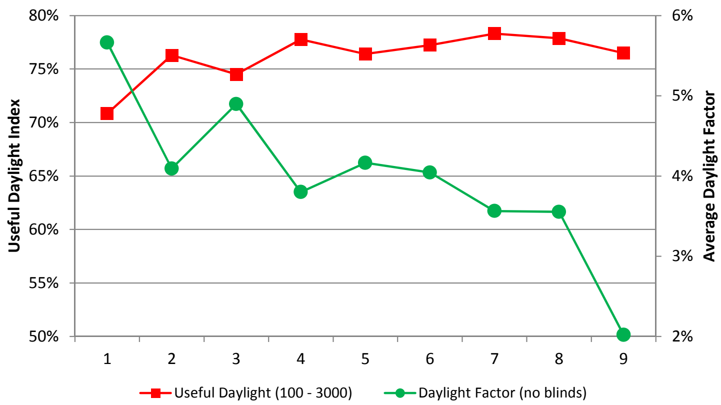


Fig 4 **Daylight factor (DF) versus Useful Daylight (UDI) in 6 m deep perimeter zone for nine façade options**

3. COMPARISON OF THERMAL AND DAYLIGHT RESULTS

To allow comparison between comfort and daylight for the different options a comparative score for each has been calculated. The number of hours that the temperature exceeds 28°C is adopted as the proxy for thermal performance. A score of 0% is given to the highest hours (178 hours for west façade option 1) and 100% to the lowest hours (67 hours for north façade option 9). The score for all other results is based on where they fall within this range. A similar approach was used for useful daylight within the first 6 m of the façade, with a score of 0% for least daylight (52% for south façade option 1) and 100% for the most daylight (83% for north façade option 8).

Figure 5 shows the comparative scores for the north, south, east and west orientations for each façade option. Figure H.18 in Appendix H was calculated based on the average of the four charts. Figure 6 shows the comparative scores for each option and orientation – the further from the centre the higher the thermal comfort and useful daylight.

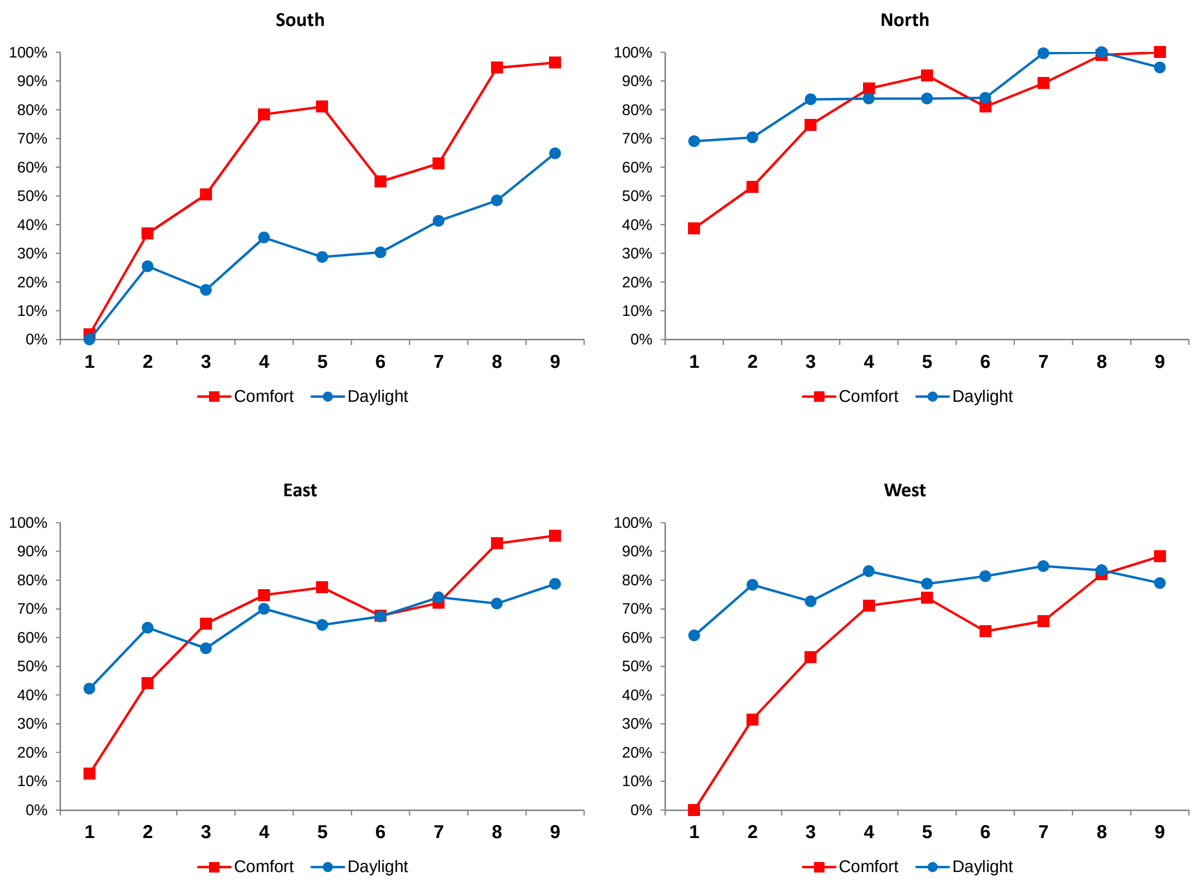
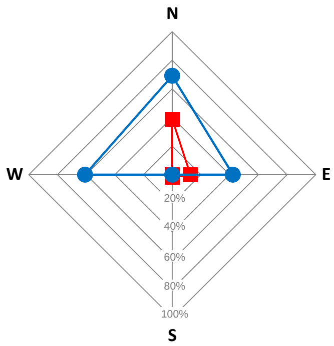
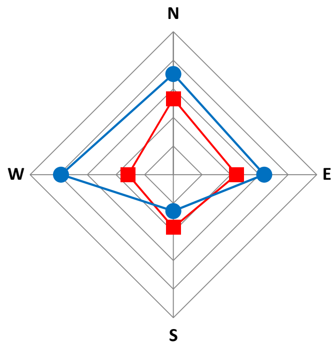


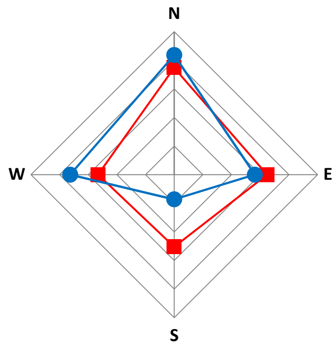
Fig 5 **Thermal comfort and daylight comparative scores for nine façade options**



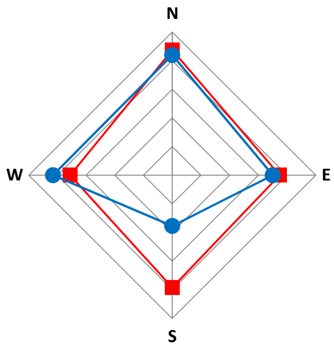
Option 1
Full height glazing
No shading
% of glass = 75% (100%)



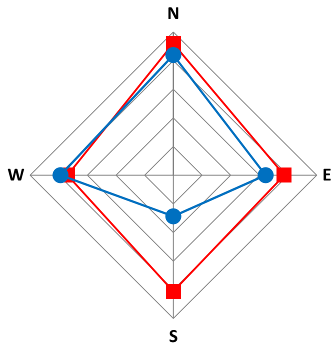
Option 2
Full height glazing
External shading @ 2.7m
% of glass = 75% (100%)



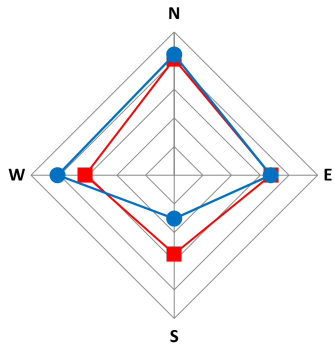
Option 3
900mm horizontal spandrel
No shading
% of glass = 50% (67%)



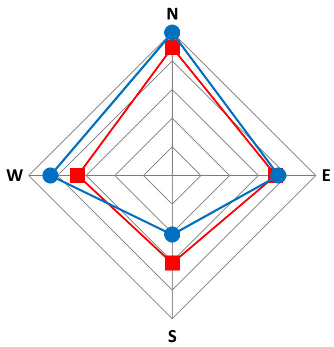
Option 4
900mm horizontal spandrel
External shading @ 2.7m
% of glass = 50% (67%)



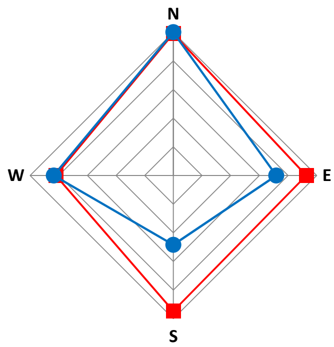
Option 5
900mm horizontal spandrel
External shading @ 2.1m
% of glass = 50% (67%)



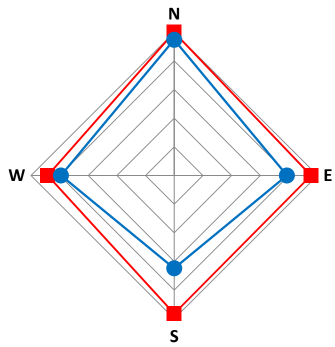
Option 6
900mm horizontal spandrel
Internal light shelf
% of glass = 50% (67%)



Option 7
Vertical glazing panels
No shading
% of glass = 50% (67%)



Option 8
Punched windows
No shading
% of glass = 33% (44%)



Option 9
Punched windows
No shading
% of glass = 25% (33%)

Fig 6 Thermal comfort and daylight comparative scores for different façade options

4. CONCLUSION

Can a fully glazed building really be considered to be low energy, even if a lot of money is spent on high performance glazing and shading systems? From this analysis it appears difficult to justify fully glazed facades from an energy, comfort or daylight perspective. This is not to say wall to ceiling glazed panels shouldn't be used, but that they should be used more imaginatively to frame views while still delivering reasonable daylight and comfort.

A ratio of 50% glazed to solid area could be considered a good starting point when considering the design of a façade.

The building was modelled with no overshadowing from adjacent buildings. This could reduce solar gain and useful daylight, which could warrant increasing glazing areas, particularly at the lower levels of a building. It is clearly important to use building physics and quantitative analysis to optimise façade design, and the methodology described in this information paper could be adopted.