Project 2: Building Project

Dungeness

Design Practice 1

Studio 1

Proposal: A landscape photography learning and art centre guided by spiritual/visual/colour and patterns. This building establishes a new landmark to explore, appreciate and marvel in the Kent landscape and environment. The key inspiration driving the concept is the 5 daily Islamic prayers that are an important pillar of the religion and in practising worshippers' lives. To capture this integral part of the communities' spiritual wellbeing and daily life, the building's architecture and programme aim to be explicitly driven by this daily cycle which is based off sun and shadow positions for each prayer. The building as a sundial will capitalise on the exposed environment at Dungeness to harness daylight, exterior views and the openness to steer its activities. The programme focuses on analogue landscape photography in light of the inspiring and unique Dungeness landscape, with activities ranging from chemically developing photographs, scanning and printing the artwork, as well as presenting it in a gallery space. The building as a sundial as well as camera aims to draw attention to diurnal visual and atmospheric changes, as well as provide frames and views to the landscape through varying orientations and altitudes. The building will incorporate structural solutions that allow for a range of open and private spaces, adapting dynamically to the different activities and sun/ light conditions. In turn, specific environmental drivers include daylight and light quality and colour. The facility accommodates for overnight stay for artists and teachers as well as day stays for visitors, with dedicated exhibition, library, living, eating and work spaces. Equinoxes and solstices, where changes in environmental conditions are most apparent and awe-inspiring. Balconies and terraces and ramps provide elevated views and variety of experiences. The designated community of users include photography students, artists, and local gallery visitors gathering to share this visual, atmospheric and spiritual experience of the building as a sundial driven by the prayer cycle.

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Technical Booklet

Part 1:

Structural Considerations:

Statement of loading conditions

(Vertical and horizontal)

Live loads:

Ground floor

Space	qk (kN/m^2)	Area (m^2)	q (kN)
Private living	2	112	224
Shared living	2	170	340
Exhibition	5	1233	6165
Art library	7.5	322	2415
glass observatory	2.5	141	352.5
Visitors entrance	3	270	810
Kitchen/ dining	3	120	360
Dark room & storage	7.5	445	3337.5
balcony	2.5	23	57.5
stairs	2	15	30
SUM			14091.5 kN

First floor

Space	qk (kN/m^2)	Area (m^2)	q (kN)
Private living	2	112	224
Exhibition	5	837	4185
glass observatory	2.5	6	15
balcony	2.5	98	245
Drying room & office	3	445	1335
roof	0.4	2641	1056.4
SUM			7060.4 kN

Qk Based on Eurocodes

Live Loads

Updated iteration in line with final design, accounting for different areas and uses of space.

Ground

Space	qk (kN/m^2)	Area (m^2)	q (kN)
Private living	2	112	224
Shared living	2	170	340
Exhibition	5	841	4205
Art library	7.5	313	2347.5
glass observatory	2.5	189	472.5
Visitors entrance	3	270	810
Kitchen/ dining	3	120	360
Dark room & storage	7.5	190	1425
balcony	2.5	26	65
stairs	2	15	30
SUM			10279 kN

First

Space	qk (kN/m^2)	Area (m^2)	q (kN)
Private living	2	112	224
Exhibition	5	837	4185
glass observatory	2.5	6	15
balcony	2.5	102	255
Drying room & office	3	190	570
roof	0.4	2641	1056.4
SUM			6305.4kN

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Technical Booklet

Snow loads

$$s = \mu_i C_e C_t s_k$$

Assumptions & Values from Eurocode 1:

- Snow load shape coefficient $\mu_i = 0.8$
- Windswept topography, exposed landscape - exposure coefficient C_e= 0.8
- Roof does not have high thermal transmittance - C_t = 1
- Altitude of site A =5m
- Zone number Z = 3
- Building is located in the UK - Snow load relationship $s_k = 0{,}140Z - 0{,}1 + \frac{A}{501}$

Load=0.33 kN/m^2

Total load = 0.8*0.8*1*0.33 =0.211kN/m^2

Roof area = =1879+141+6+445+170=2641m^2

Snow load= 557.45kN. This load is supported by the roof truss structure which is demonstrated further on.

Wind loads

We	qp*Cpe	
qp	qp(Ze)	
Façade base>height uniform wind load		
A	1 m	
Z	8 m	
Vb	22.524	
Cdir	1	
Cseason	1	
Cprob	1	
Calt	1.01	
Vbmap	22.5	
Ce (z)	3.5	
qb	0.311	(kN)
qp	1.088	(kN/m^2)
Windward load	0.871	(kN/m^2)
Leeward load	0.544	(kN/m^2)

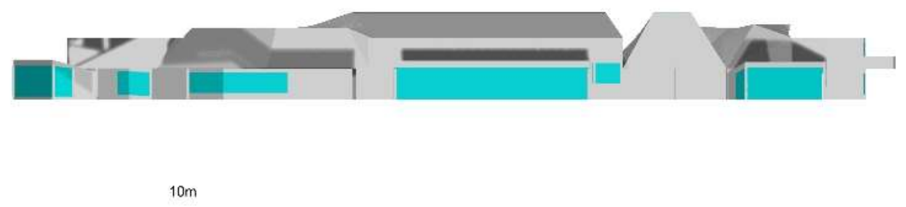
<u>Mitigation of wind loads- considerations:</u>

- Shear wall for solid walls- in dark room interior walls
- Bracing along the height of the façade

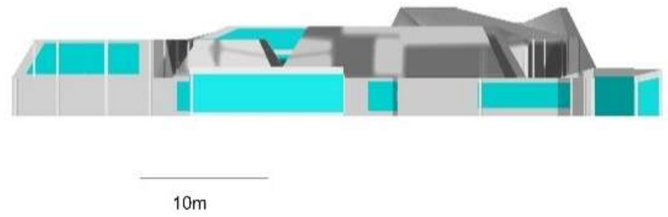
Lateral Load Resistance

Largest area facing the wind is used to size bracing. The south and west elevations are selected to account for a worse-case scenario of high wind loads, with 0.544kN/m^2 and 0.871kN.m^2 for south and west elevations respectively based on previously calculated wind loads.

Long elevation



Short elevation



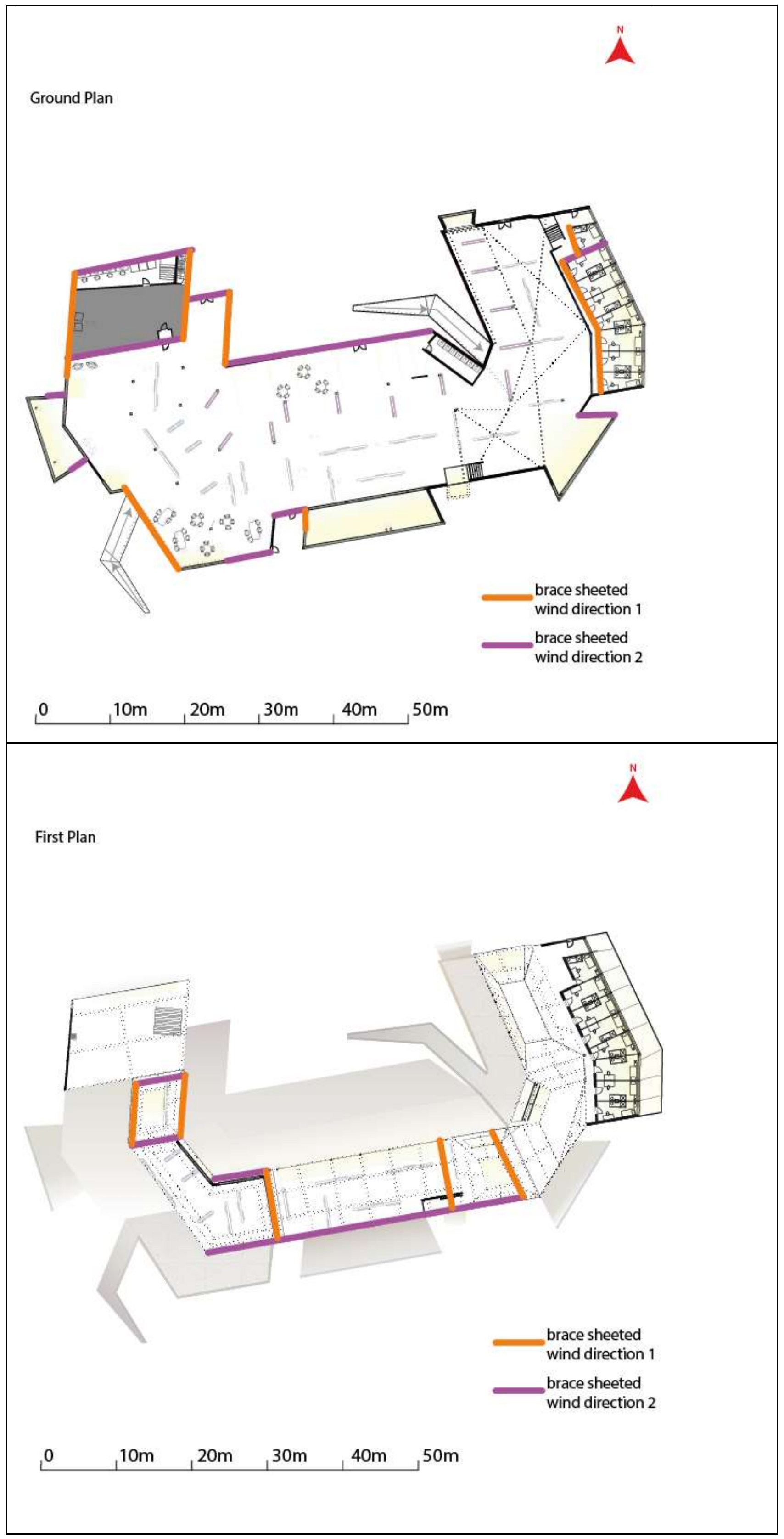
<u>Assumptions:</u>

- Use half façade height (1.5m per storey) for calculating nominal bracing elevation area following standards. This is a conservative approach to assume that only half the wall will provide wind load resistance.
- Use largest façade areas to find wind load to account for the highest wind loads, and this is done by using the longest 2 facades: the south and west elevations.

Nominal wall bracing - (bracing already in the internal lining of the building from the solid walls.) This is illustrated in orange and purple above. Finding the nominal bracing indicates the building's in-built capacity to resist the wind load, and therefore I can size the additional bracing required. Some recommendations from standards include:

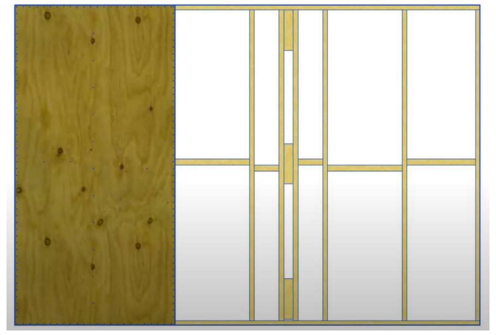
- Max. allowance for nominal bracing = 50%
- Should be evenly distributed otherwise ignored
- Sheeted one side only 0.45 kN/m bracing capacity. This is the capacity of an external wall to resist wind loads. It is lower as an external wall can only resist in one side.
- Sheeted 2 sides 0.75 kN/m bracing capacity (internal). This is the capacity of an internal wall to resist wind loads. It is higher as an internal wall can resist winds on both sides.
- Wall length determined by finding length of walls perpendicular to wind direction

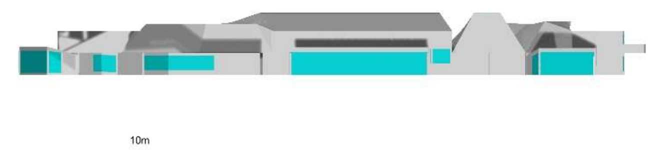
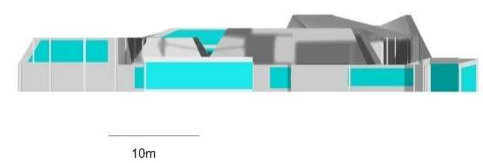
The floorplan and existing walls are used to space the shear walls. The orange show walls that take wind loads from the west direction, and purple shows walls that take wind load in south direction. These are existing solid walls in plans and are the 'nominal' bracing component provided by the building structure itself. It is important that these walls are evenly spread and span the full height of the 2 storeys to be effective at resisting lateral loads and to prevent discontinuity in the bracing.



Bracing option selected is 7mm Plywood with a resistance of 8.7kN/m based on table 8.18 bracing systems from guidelines.

A 1.2m standard sheet= 8.7* 1.2= 10.5 kN resistance per sheet. This is the additional bracing, and the number of sheets required is found after finding the nominal bracing resistance and then finding the additional required bracing to account for the total wind load.



Long elevation	Short elevation
	

		Long elevation		Short Elevation	
Area of wall	m^2	125		76	
Area of roof		270		155	
Total area		395		231	
Wind load	kN/m ^2	0.544		0.871	
Wind Force	kN	215		201	
Nominal Bracing capacity	kN/m	0.45 (external)	0.75 (internal)	0.45 (external)	0.75 (internal)
Wall length (ground + 1st floor)	m	50+17	23+29	69+53	22+13
Resistance	kN	30.2	39	54.9	26.3
Total nominal resistance	kN	69.2		81.2	
Additional Require bracing	kN	215-69.2=145.8		201-81.2= 119.8	
Bracing sheets needed		145.8/10.5=13.9		119.8/10.5=11.4	
Overall bracing requirement		14 sheets in wind direction 1 for long elevation		12 sheets for wind direction 2 in short elevation	

A higher wind load has been considered to factor for averaging the wind loads by all the shear walls, as this may not be the actual wind load distribution.

Kent vernacular architecture & materials

English vernacular buildings are built either with mass walls (of stone, brick or mud) or with timber-framed walls, or with a combination of the two.
Walling and roofing materials are locally derived

An oast or hop kiln is a building designed for kilning (drying) hops as part of the brewing process.
Oasts were built of various materials, including bricks, timber, ragstone, sandstone. Cladding could be timber weatherboards, corrugated iron or asbestos sheets.

Caring Wood Country architecture by James Macdonald Wright and Niall Maxwell inspired by traditional oast houses of Kent

the tile-hung houses, great catslide roofs and outshuts.

Based on information from https://architecturetoday.co.uk/made-of-kent/

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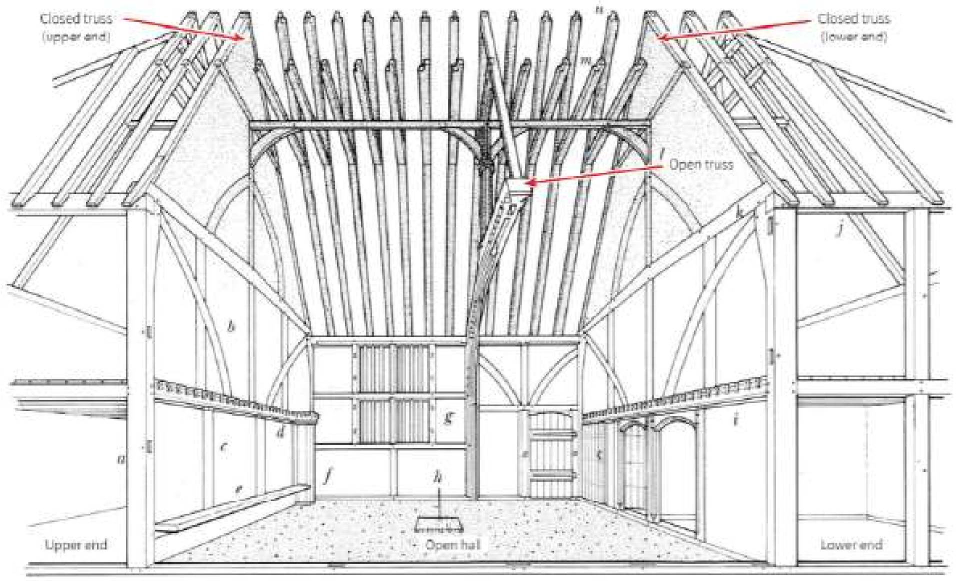
Timber frame:

- easy to build on a concrete raft 'floating' on EPS insulation, to eliminate thermal bridging
- avoid thermal bridging caused by solid studs, and use I-beams or a two layer wall with an inner structure and outer insulation wrap
- airtightness achieved with a membrane or racking board with tape over joints
- avoid elements of structure crossing the thermal envelope
- avoid heavy cladding that might require a separate foundation

Traditional masonry:

- very wide insulated cavities between inner and outer masonry and thermal bridge free ties
- airtightness can generally be achieved with parge or plaster



a main post
b brace
c stud
d dias beam
e dias bench
f spere
g hall window
h open hearth
i lower end beam
j wall plate
k tie beam
l crown post
m collar
n rafter

Passivhaus guidance
avoid mixing different systems within one building- this introduces interfaces that will make achieving Passivhaus challenging and more expensive than it needs to be , local builders are experienced in traditional masonry, choose masonry as you are more likely to achieve Passivhaus by working with the available skill base, ensure that orientation, form and fenestration are optimised

Based on Historic England Domestic 1: Vernacular Houses document https://historicengland.org.uk/images-books/publications/dlsg-vernacular-houses/heag102-domestic1-vernacular-houses-lsg/

Following this research, I decided to use a combination of timber-framed walls with a gabion feature to link to the Kent vernacular as well as to the shingle landscape, especially using local materials including flint. Timber beams and columns are the vertical load bearing system, and the gabions are also part of the vertical load bearing system. Solid walls are the shear walls for lateral stability, as well as using additional internal and external braces.

Materials Catalogue

Material	Where	Structural function
Glulam timber	Throughout	Beams and columns
CLT	Throughout	Floor slabs
Gabion	Front façade, around art library and visitors' entrance	Nominal bracing, shear wall
Timber cladding	All other facades	
Glass	Glass pods and windows	
Plywood sheet	Internal and external solid walls	Bracing

Gabions

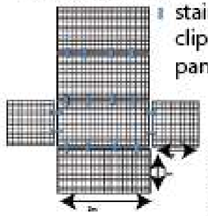
Herzog de Meuron winery, California
Porous material, 1 layer thick, allowing for sunlight to enter
Adapt this idea using local flint to make gabions

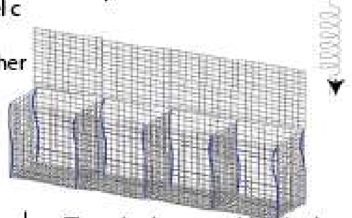
Gabion wall example

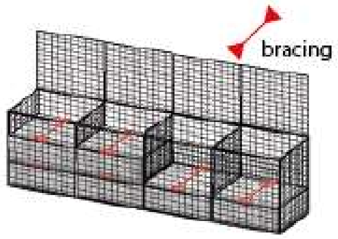
helicoils, which are long springs that you wind down the corners of the baskets. These springs attach the front and side panel of a basket and its adjacent panel in one go (4 sides).

When filling the baskets it is necessary to insert a brace in the middle of the basket. This is important to stop the face bulging when filling.

Making a Gabion

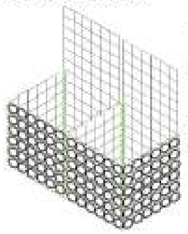






There is also a partition in the middle of this basket which is clipped in as well.

Filling the gabiions



The stone should be laid flat and attention taken to avoid voids

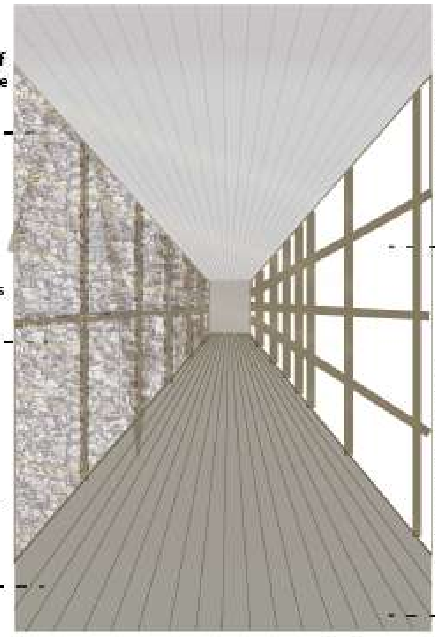
2 springs per basket and 2 extra for the end of a run (in the case of 1m cubes).

1/3rd fill the basket and then create a windless which are the red ties
Make a loop from the back to the front of the basket and join the ends with pliers. Put a sturdy flat stone in this loop and turn in circle creating a tourniquet effect which pulls the front tight. Fill on top of this which will hold the stone in place. Repeat 2/3rds of the way up.

Finally lace the lids down with the lacing wire provided.

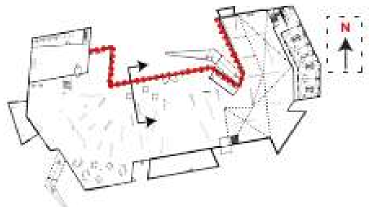
Gabion Light Feature Case Study

Dominus Winery by Herzog de Meuron, Yountville, California, Completed in 1997

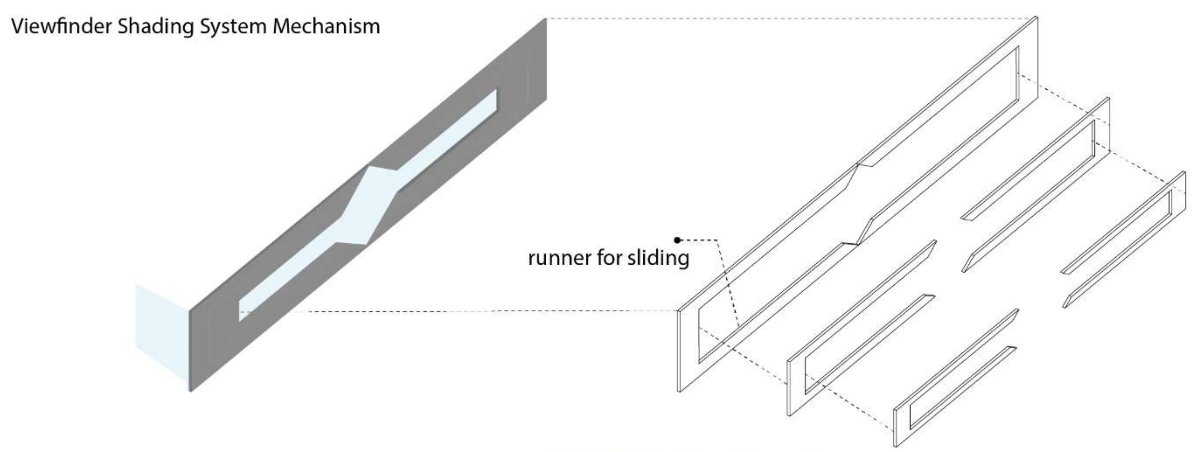


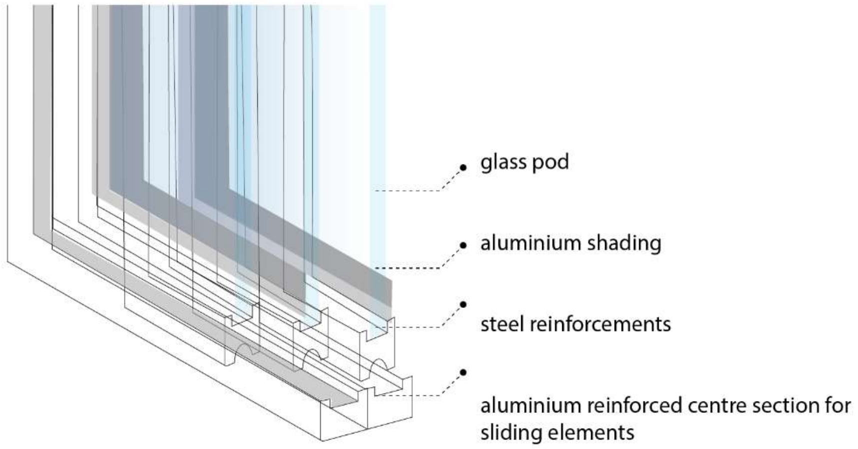
Gabion Wall Details

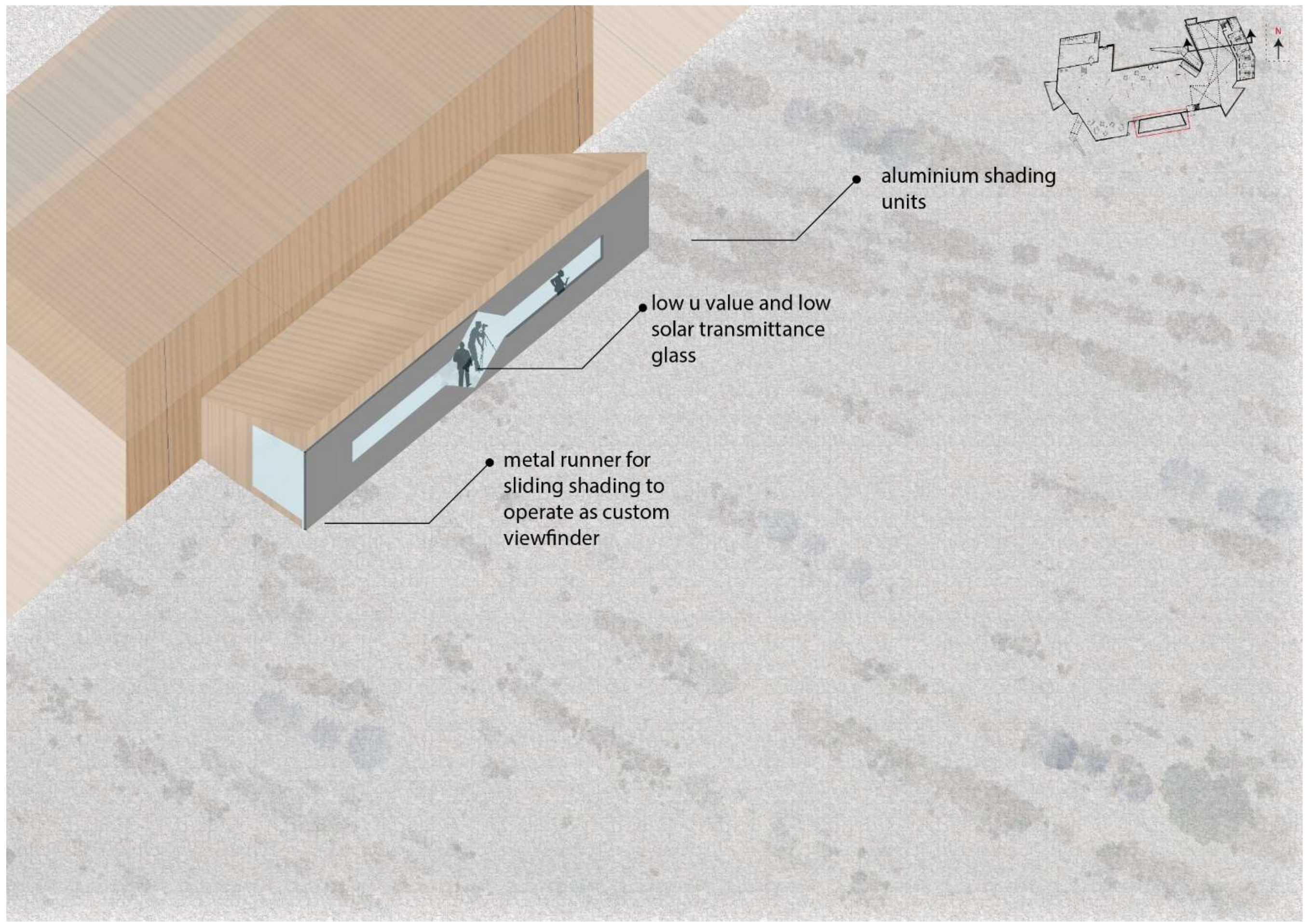
Gabion wall with internal glass membrane at entrance leading to art library and gallery space
illustrating light quality at entrance



Glass pod, viewfinder







Beam type selection

Glulam beams selected for the timber frame for their high strength and long span which allows for continuous open plan spaces such as the exhibition space.

Other advantages include

- Stability: Glulam is a laminated composite product of high strength lumber. This randomizes any natural defects so there is greater beam strength, reliability, less likelihood of warping,
- Moisture Control.
- Fire Performance:
- Quality Assurance: Glulam is manufactured in accordance with ANSI/A190.1

Beam Sizing

To size the beams I start in reverse order: from the slab load on secondary beams, then load on primary beams, perimeter beams, and lastly sizing the columns that carry the load of slabs, primary, secondary and perimeter beams. This order is followed to ensure that component provides enough resistance.

Properties for CLT slabs are listed below here: and the slab load of 0.245 kN/m^2 is used.

Bending strength MPa	30
density kg/m^3	460
unit mass kg/m^2	1840
unit weight kN/m2	18.032
slab load	0.245

Source: CLT handbook Swedish wood https://www.woodcampus.co.uk/wp-content/uploads/2019/05/Swedish-Wood-CLT-Handbook.pdf

Loads are used to size secondary beams in each space, varying the live load. Factors of safety are based off of Eurocode 7.

Load component	Load on secondary beams (kN/m^2)	Factor of safety
live	Depending on space	1.5
flooring	0.3	1.35
MEP	0.1	1.35
		1.35
ceiling	0.1	1.35
slab	0.245	1.5
SUM		
Assumption: CLT 25kg/m^2, 10m span, 250mm thickness		

These loads are represented as the 'total loads' row in the next table, for example total load in the ground floor private living space $=(1.35_1*(0.3_2+0.1_3+0.1_4))+(1.5_1*(0.245_5+2_6))$ =3.0425 kN/m^2, where

1. Factor of safety
2. Flooring
3. MEP
4. Ceiling
5. Slab
6. Occupancy live load

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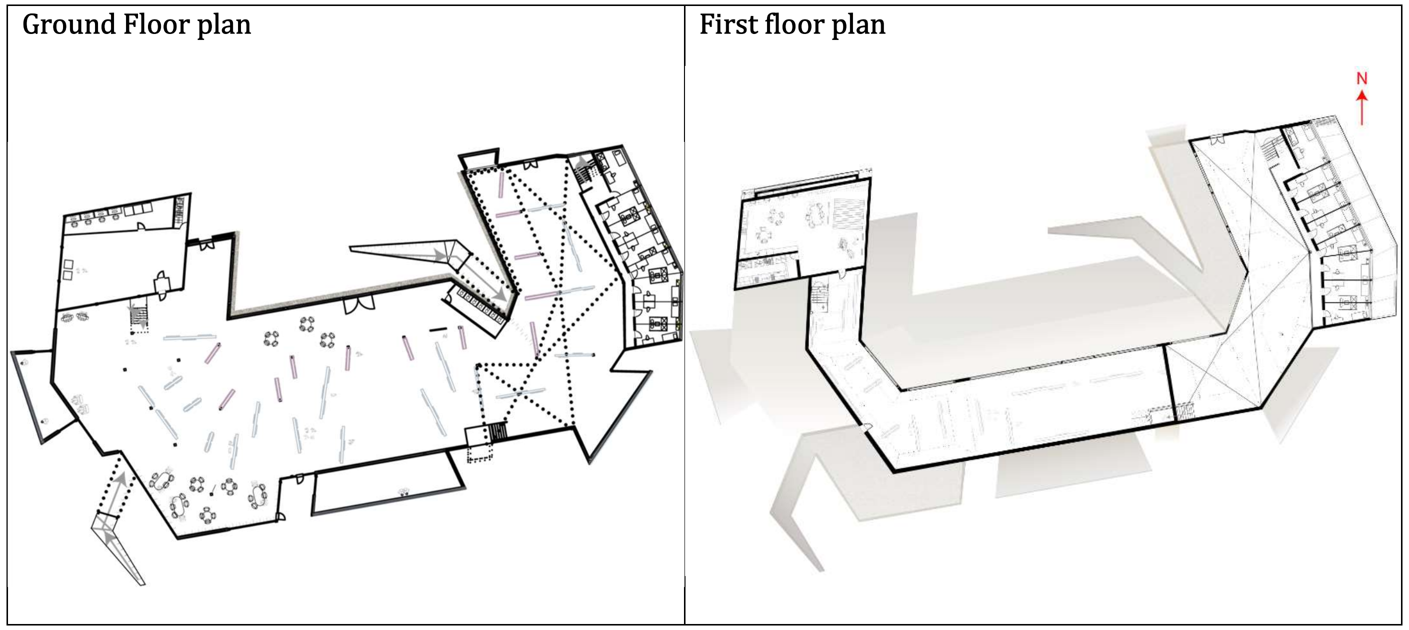
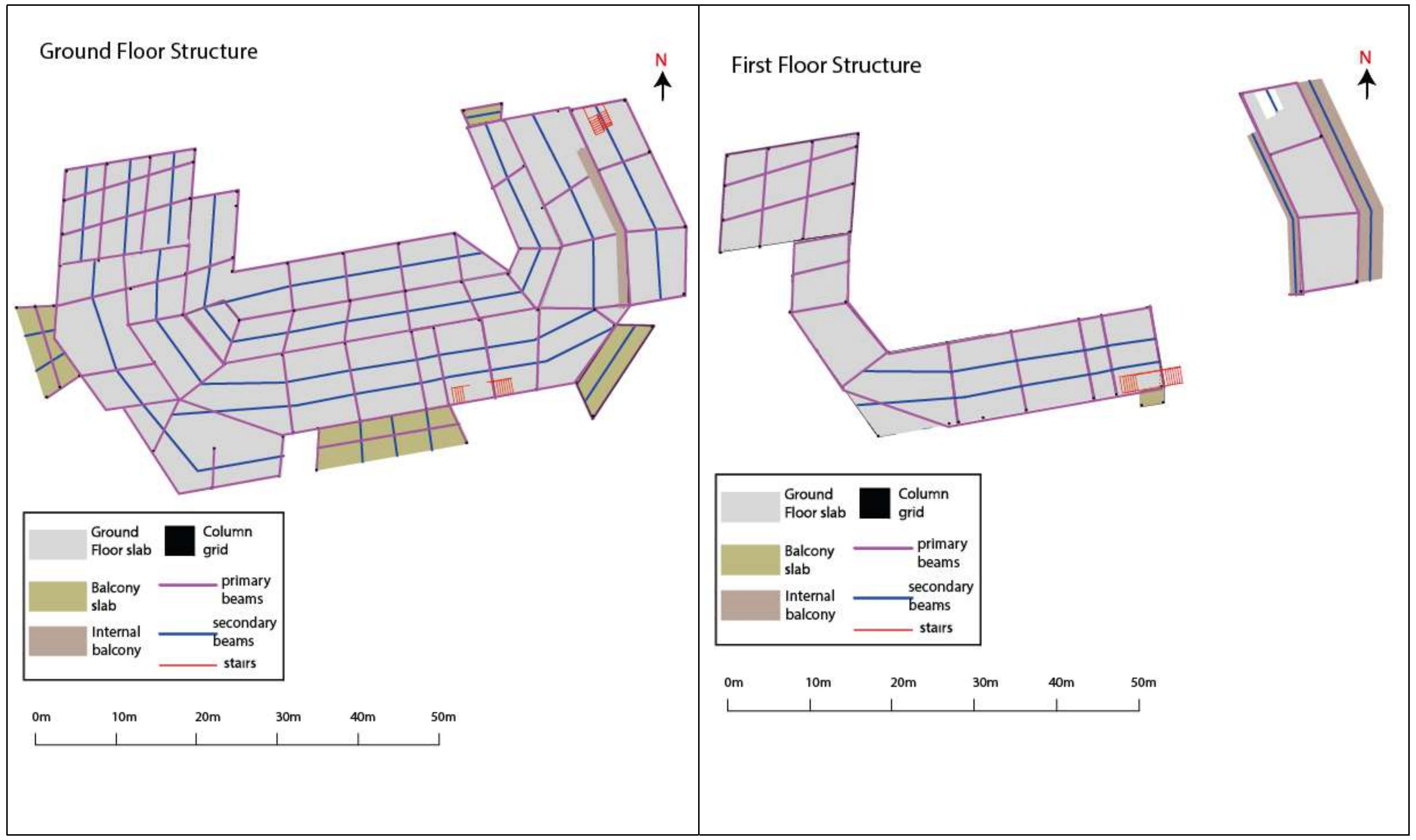
Secondary beam sizing:



First iteration

The columns and primary beams are arranged based on the floorplan divisions of spaces and uses, while taking into account the important of maintaining a line of vision in some key areas such as the gallery. This is to account for the different anticipated loads in each area and to size beams accordingly.

In the images below, the preliminary arrangement is shown. The column spacing is 10m maximum in line the beam's maximum span. The green areas are for the glass pod/ balcony where visibility is especially important and columns must not get in the way of the view out to the landscape, therefore the columns are on the perimeter.

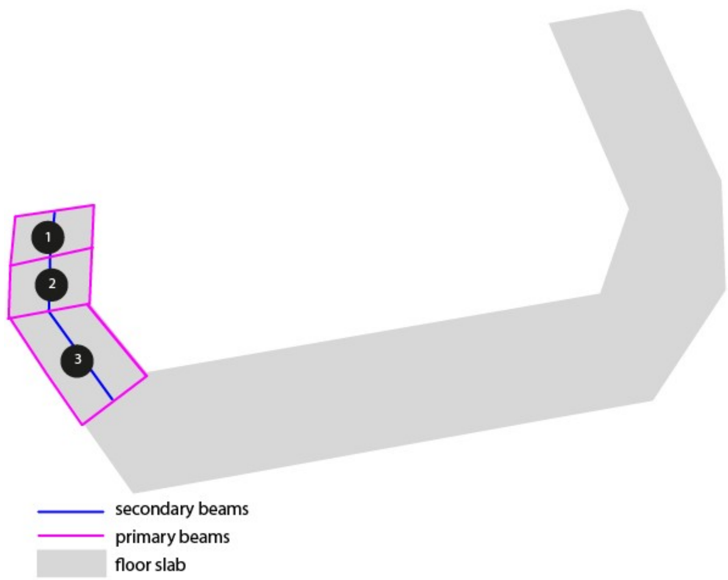


This iteration plans for secondary beams with spacing of around 4m, with a beam cross section 0.25*0.25m therefore moment of inertia I= 0.000326. However, it becomes clear that this spacing is too far away as the moments on the beams are too large, therefore the next iteration spaces the secondary beams much closer together.

The next table shows the steps to find the moments developing in the secondary beams.

For some large spaces with complex plans, the floor area is split into several smaller plans and beams are sized for each area separately, then using the worst-case to use the beams for the entire area.

For example, the exhibition space is split into 3 areas each with a different tributary area and beam length. The second zone has the highest moments and needs the stiffest beams, so this beam size is used for the entire space. This is shown in the exhibition space having 3 rows for tributary areas and 3 calculations for moment, then the maximum one is chosen to account for the worse-case.



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Space	Private living	Shared living	Exhibition	Art library	glass observatory	Visitors entrance	Kitchen/ dining	Dark room & storage	balcony
Total load (kN/m^2)	3.0425	3.0425	6.0425	8.5425	3.5425	4.0425	4.0425	8.5425	3.5425
Tributary area	112	42	213	313	9	270	120	63.33333	26
		86	252.5		45				
		42	123		30				
					30				
load kN	340.76	127.785	1287.053	2673.803	31.8825	1091.475	485.1	541.025	92.105
		261.655	1525.731		159.4125				
		127.785	743.2275		106.275				
					106.275				
length m	26	4.6	26	65	4.5	49	22	12	20.7
		9.5	54		11.3				
		5.3	18		5				
					4.3				
Distributed load kN/m	13.10615	27.77935	49.50202	41.13542	7.085	22.275	22.05	45.08542	4.449517
		27.54263	28.25428		14.1073				
		24.11038	41.29042		21.255				
					24.71512				
M (kNm) wl^/8	1107.47	73.47638	4182.921	21724.65	17.93391	6685.284	1334.025	811.5375	238.3217
		310.7153	10298.69		225.1702				
		84.65756	1672.262		66.42188				
					57.12281				
I	0.000326								
m= m/I * h/2	425268.5	28214.93	1606242	8342264	6886.62	2567149	512265.6	311630.4	91515.53
		119314.7	3954695		86465.34				
		32508.5	642148.6		25506				
					21935.16				
M max (kPa)	425268.5	119314.7	3954695	8342264	86465.34	2567149	512265.6	311630.4	91515.53
M max (MPa)	425.2685	119.3147	3954.695	8342.264	86.46534	2567.149	512.2656	311.6304	91.51553

Conclusions: very high moments develop in beams (orange) due to sparse secondary beams and small cross section. These cannot be taken by glulam beams.

This needs to be addressed in a second iteration with a smaller spacing of secondary beams and different beam cross sections.

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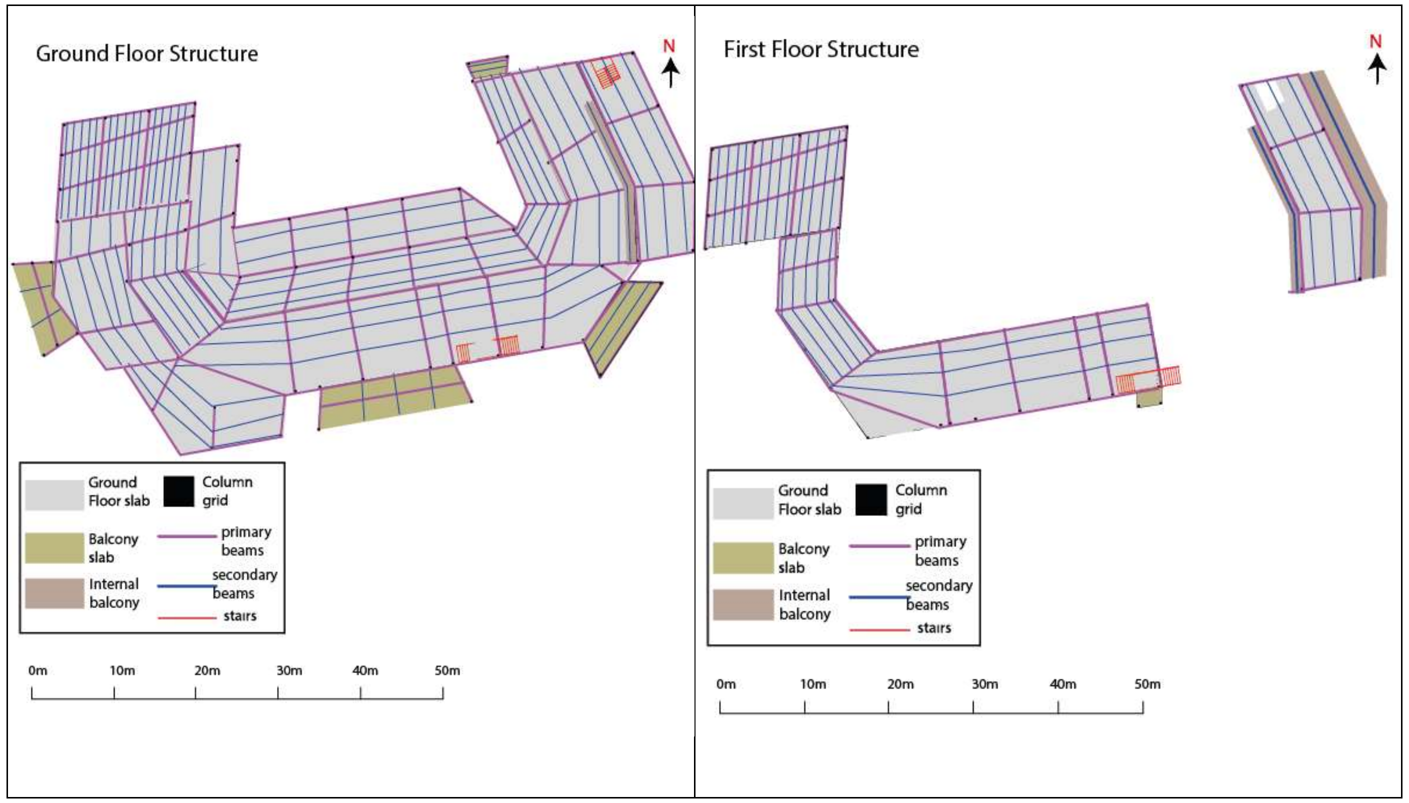
Iteration 2:

Secondary beams are spaced with around 1m in between instead of 4m, and a larger beam cross section is selected: 0.45*0.25m. This increases the moment of inertia I and provides higher resistance.

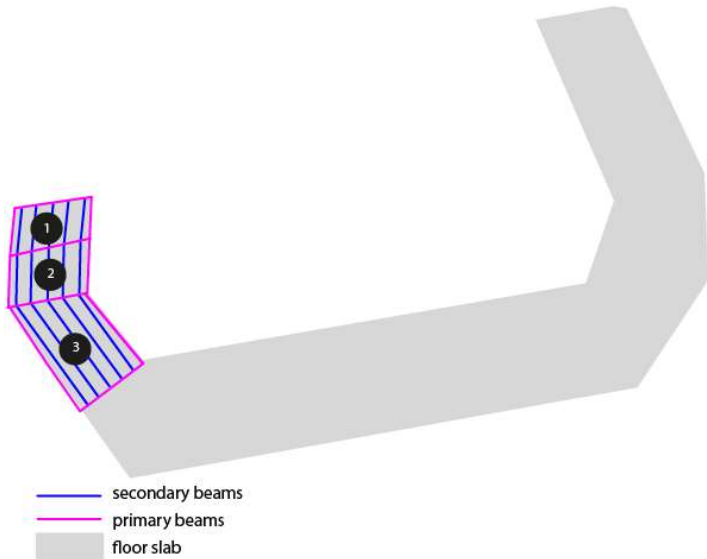
The images below show the new, closer secondary beam configuration.



For complex shapes for spaces such as the gallery space, only the worst-case scenario is considered, i.e. the longest beam span a part of the total area, then this is used to size beams for the whole space.

For some large spaces with complex plans, the floor area is split into several smaller plans and beams are sized for each area separately, then using the worst-case to use the beams for the entire area.

For example, the exhibition space is split into 3 areas each with a different tributary area and beam length. The second zone has the highest moments and needs the stiffest beams, so this beam size is used for the entire space.



Space	Private living	Shared living	Exhibition	Art library	glass observatory	Visitors entrance	Kitchen/ dining	Dark room & storage	balcony
Total load (kN/m^2)	3.04	3.04	6.04	8.54	3.54	4.04	4.04	8.54	3.54
Tributary area	17.83	14.00	5.20	15.33	4.50	27.15	6.83	12.67	4.30
	21.50	17.20	6.80		22.50		18.83		11.20
	21.50	14.00	12.60		30.00		31.44		10.50
					30.00				
load kN	54.26	42.60	31.42	130.99	15.94	109.75	27.62	108.21	15.23
	65.41	52.33	41.09		79.71		76.13		39.68
	65.41	42.60	76.14		106.28		127.11		37.20
					106.28				
length m	7.60	4.80	3.80	10.50	4.50	9.00	4.00	12.00	3.30
	9.30	9.50	4.70		11.30		8.20		8.10
	9.10	5.30	9.40		5.00		9.00		9.30
					4.30				
load kN/m	7.14	8.87	8.27	12.47	3.54	12.19	6.91	9.02	4.62
	7.03	5.51	8.74		7.05		9.28		4.90
	7.19	8.04	8.10		21.26		14.12		4.00
					24.72				
M (kNm) wl^/8	51.55	25.56	14.92	171.92	8.97	123.47	13.81	162.31	6.28
	76.04	62.14	24.14		112.59		78.04		40.17
	74.41	28.22	89.46		66.42		143.00		43.24
					57.12				
I	0.000586								
h/2	0.125								
m= m/I * h/2	10996.27	5452.16	3183.99	36675.8	1912.95	26340.93	2946.53	34625.6	1340.48
	16222.61	13257.19	5149.82		24018.15		16647.91		8570.02
	15873.74	6020.09	19084.63		14170.00		30507.4		9224.67
					12186.20				
M max (kPa)	16222.61	13257.19	19084.63	36675.8	24018.15	26340.93	30507.4	34625.6	9224.67
M max (MPa)	16.22	13.26	19.08	36.68	24.02	26.34	30.51	34.63	9.22
Glulam option	1	1	1	4	2	2	3	4	2
unit weight of beam (kN/m)	0.42	0.42	0.42	0.51	0.45	0.45	0.47	0.51	0.42

Conclusions:

The maximum moments that develop in the beams (green) are much smaller and below the beam's capacity, therefore this spacing of beams is appropriate.

To conserve materials, different beam sizes are used rather than the standard 0.25m x 0.25m and 30MPa strength standard assumed in the first iteration.

For example, the shared living space has a relatively low maximum moment of 13.3MPa so the glulam option 1 is selected with a unit weight of 0.41895 kN/m, whereas the art library has a higher maximum moment of 36.7 MPa for beams due to high loads of books so the glulam option 4 is selected with a higher unit weight of 0.50715 kN/m.

This reduces the self-weight of the timber structure by specifying smaller beams for spaces loaded less heavily.

Glulam option	strength MPa	density (kg/m^3)	weight per m (kN/m)
1	24	380	0.41895
2	28	410	0.452025
3	32	430	0.474075
4	38	460	0.50715

Based on Archi expo glulam catalogue at https://pdf.archiexpo.com/pdf/metsaewood/glulam/60821-136465-_10.html

It's also important to note that for the art library and exhibition space, only the worse-case portion of the plan area was considered then applied to the entire space.

Primary beam sizing

Based on iteration 2 of secondary beams. Primary beams take the load supported by the slabs and secondary beams, as well as their self-weight.

Space	Private living	Shared living	Exhibition 1	Art library 4	glass observatory	Visitors entrance	Kitchen/ dining	Dark room & storage	balcony
Glulam secondary beam option	1	1	1	4	2	2	3	4	2
unit weight of beam (kN/m)	0.41895	0.41895	0.41895	0.50715	0.452025	0.452025	0.474075	0.50715	0.41895
length of secondary beam m	38.7	38.0	47.5	29.1	10.6	18.0	23.5	17.0	3.3
secondary beam load kN	16.2	15.9	19.9	14.8	4.8	8.1	11.1	8.6	1.4
tributary area	42.5	42.5	63.0	46.0	22.5	52.5	54.3	21.1	4.3
previous load (kN/m^2) (from live load MEP, flooring etc.)	3.0	3.0	6.0	8.5	3.5	4.0	4.0	8.5	3.5
previous load (kN)	129.3	129.3	380.7	393.0	79.7	212.2	219.5	180.3	15.2
total load on primary (kN)	145.5	145.2	400.6	407.7	84.5	220.4	230.6	189.0	16.6
length primary m	7.5	9.2	7.0	9.4	4.9	13.0	6.0	19.3	1.4
primary beam distributed load (kN/m)	19.4	15.8	57.2	43.4	17.2	17.0	38.4	9.8	12.3
M (kNm) wl^/8	136.4	167.0	350.5	479.1	51.7	358.1	173.0	455.9	2.8
I	0.000586	0.000586	0.001758	0.0030375	0.000585938	0.001758	0.000586	0.003038	0.0000125
h/2	0.125	0.125	0.1875	0.225	0.125	0.185	0.125	0.225	0.05
m= m/I * h/2	29106.0	35628.9	37387.2	35486.1	11038.1	37687.8	36903.8	33768.4	11215.3
M (MPa)	29.1	35.6	37.4	35.5	11.0	37.7	36.9	33.8	11.2
Glulam option	2	4	4	4	2	4	4	4	1
unit weight of beam (kN/m)	0.452025	0.50715	0.6762	0.81144	0.150675	0.6762	0.50715	0.81144	0.05586

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Beams are also varied based on load requirements, with different cross sections used:

cross section 0.45 x 0.25m
cross section 0.4 x 0.375m and 0.4 x 0.45m for higher strength
cross section 0.15 x 0.1m for lower strength

This also affects the moment of inertia I. By choosing larger cross sections and especially larger heights of cross sections, this provides a larger I and larger resistance in the beams to meet the higher moment imposed.

Perimeter beam sizing

These beams are loaded with the wall weight and cladding.

Based on Timber Tecs weight of walls http://www.timbertecs.co.uk/blog/2011/11/how-much-will-the-timber-frame-for-my-house-

external wall unit weight (kg/m^2)	5.8	kg/m^2 wall							
internal wall unit weight (kg/m^2)	2.0	kg/m^2 wall							
Total	0.0763	kN/m^2 wall							
3m storey height	0.229	kN/m wall							
perimeter length	340.0	m							
beam length	10.0	m							
Load (3m wall * perimeter)	77.9	kN							
M (wl^2/8)	2.9	kNm							
Selected beam cross section	0.45 x 0.25	0.45 x 0.25	0.4 x 0.375	0.4 x 0.45	0.45 x 0.25	0.4 x 0.375	0.45 x 0.25	0.4x 0.45	0.15 x 0.1
I	0.000586	0.000586	0.001758	0.0030375	0.000586	0.001758	0.000586	0.0030375	1.25E-05
h/2	0.125	0.125	0.1875	0.225	0.125	0.185	0.125	0.225	0.1
m	610.7	610.7	305.4	212.1	610.7	301.3	610.7	212.1	11451.3
M MPa	0.6	0.6	0.3	0.2	0.6	0.3	0.6	0.2	11.5
Max MPa	11.5	Cross section	0.15 x 0.1 m	Unit weight of perimeter beam (kN/m^2	0.05586				

weigh.html#:~:text=One%20cubic%20metre%20of%20softwood,for%20the%2075m2%20roof

The moment is found 2.9 kNm, and the different beam options are assessed to find the dimension that will be able to resist this moment. Finally the beam with dimensions 150 x 100 mm is chosen with a unit weight of 0.05586kN/m^2. This weight is loaded on the columns.

Column Sizing:

Cross section 0.1m^2 dimension with density 56kg/m^3 therefore unit weight of glulam columns are: 0.005488 kN/m. This is based on weight of engineered wood from Roof Online catalogue for glulam beams depending on cross section from https://roofonline.com/weight-of-engineered-wood
Columns are sized to support the primary beams and previous loads of secondary beams, live loads and dead loads, (MEP etc.). Once this total load is found it is divided by the number of columns in the tributary area to find the pressure on columns (green). Finally, the self-weight of columns is found by summing the self-weight of all columns in the ground floor (78).

Space	Private living	Shared living	Exhibition 1	Art library 4	glass observatory	Visitors entrance	Kitchen/ dining	Dark room & storage	balcony
Glulam primary beam option	2	4	4	4	2	4	4	4	1
unit weight of beam (kN/m)	0.5	0.5	0.7	0.8	0.2	0.7	0.5	0.8	0.1
length of primary beam m	7.5	9.2	7.0	9.4	4.9	13.0	6.0	19.3	1.4
primary beam load kN	3.4	4.7	4.7	7.6	0.7	8.8	3.0	15.7	0.1
total load on primary (kN)	145.5	145.2	400.6	407.7	84.5	220.4	230.6	189.0	16.6
tributary area	42.5	42.5	63.0	46.0	22.5	52.5	54.3	21.1	4.3
previous load (kN)	145.5	145.2	400.6	407.7	84.5	220.4	230.6	189.0	16.6
perimeter beam length	26.0	5.3	3.2	8.1	36.6	8.5	11.0	5.0	0.0
perimeter beam load	1.5	0.3	0.2	0.5	2.0	0.5	0.6	0.3	0.0
total load on columns (kN)	150.4	150.2	405.5	415.8	87.3	229.6	234.3	204.9	16.7
number of columns	2	2	2.7	2.5	3	4	2	1.3	1.5
load on column kN	75.2	75.1	152.1	166.3	29.1	57.4	117.2	153.7	11.1
Pressure MPa	7.5	7.5	15.2	16.6	2.9	5.7	11.7	15.4	1.1
column unit weight	0.005488								
total no of columns in space	6	4	18	10	16	8	4	10	2
total column load of space	1.27596 kN								

Note: Exhibition area 1 and art library area 4 are the worst loaded areas of the spaces and are used to size the columns.

Total loads

Total vertical load for ground floor from live loads MEP, ceiling, floor, slabs, secondary, primary and perimeter beams, and columns. This is a summation of the previously found live and dead loads, as well as the self-weight of structural members.

	primary beams	Space	Private living	Shared living	Exhibition 1	Art library 4	glass observatory	Visitors entrance	Kitchen / dining	Dark room & storage	balcony
Secondary beams	unit weight of beam (kN/m)		0.42	0.42	0.42	0.51	0.45	0.45	0.47	0.51	0.42
length			77.50	76.00	319.00	187.00	55.00	92.00	61.00	175.50	20.70
weight			32.47	31.84	133.65	94.84	24.86	41.59	28.92	89.00	8.67
Primary beams	unit weight of beam (kN/m)		0.45	0.51	0.68	0.81	0.15	0.68	0.51	0.81	0.06
length			15.20	30.00	189.00	96.30	105.00	75.00	15.00	115.00	2.60
weight			6.87	15.21	127.80	78.14	15.82	50.72	7.61	93.32	0.15
Perimeter beams	unit weight of beam (kN/m)		0.06								
length			26	5.3	3.2	8.1	36.6	8.5	11	5	0
weight			1.45	0.30	0.18	0.45	2.04	0.47	0.61	0.28	0
Columns	column unit weight (kN/m)		0.005488								
	total no of columns in space		6	4	18	10	16	8	4	10	1.5
	total column load of space		1.28	kN							
Other loads			340.00	340.00	4205.00	2347.50	472.50	810.00	360.00	1425.00	65.00
Total			380.79	387.35	4466.63	2520.93	515.23	902.78	397.14	1607.60	73.82
Overall	11253.54 kN										

This is repeated similarly for the first floor which is a reduced plan containing only private living, exhibition and office/storage spaces. Therefore the first floor is counted as a repetition but for only the specified spaces.

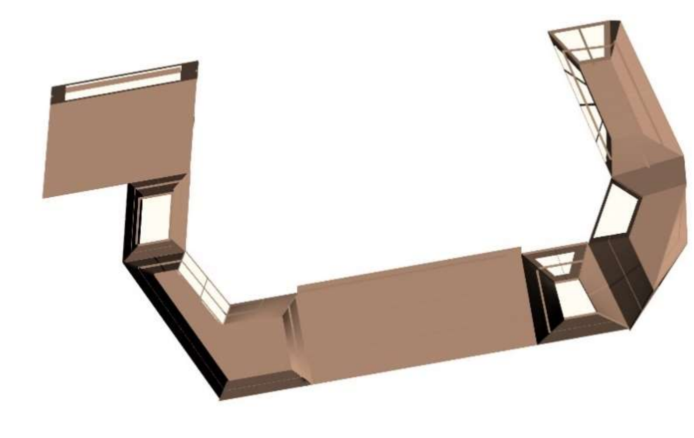
Total loads

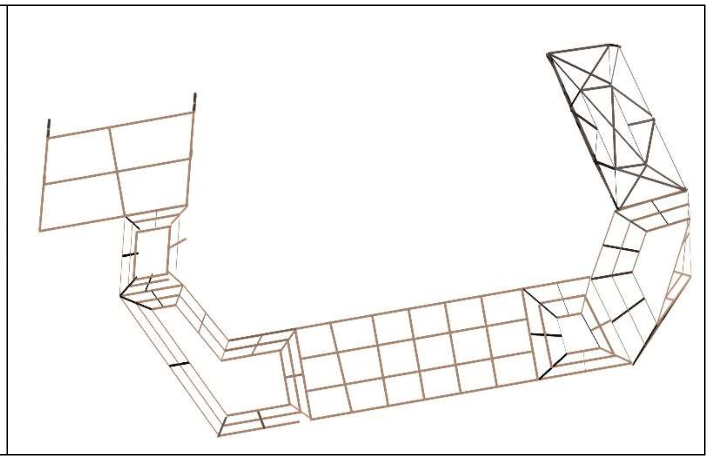
Ground floor overall	11253.54 kN	Primary, secondary, perimeter beams, columns, and live and dead loads
First floor simplification	6528.835	primary, secondary and perimeter beams and live and dead loads
	0.584472	Columns
First floor sum	6529.419 kN	Total for first floor (private living, balconies offices, gallery)
Load on Both floors sum		17782.95 kN

To find the total vertical load, it is still necessary to add the roof loads and gabion wall load. These are found:

Roof

Overall roof structure of the roof and roof truss is shown here:

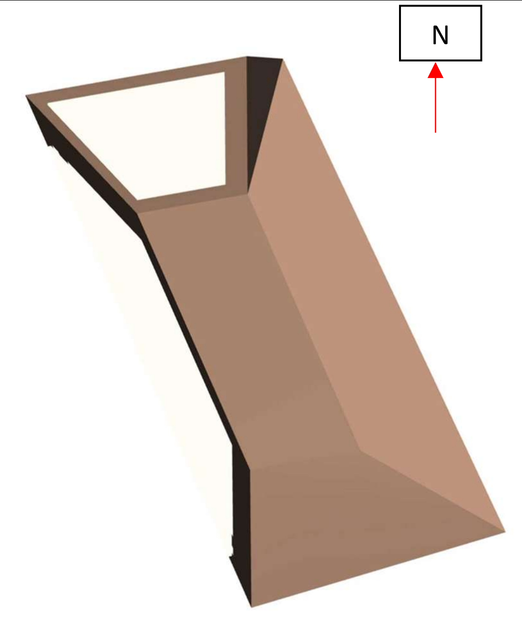


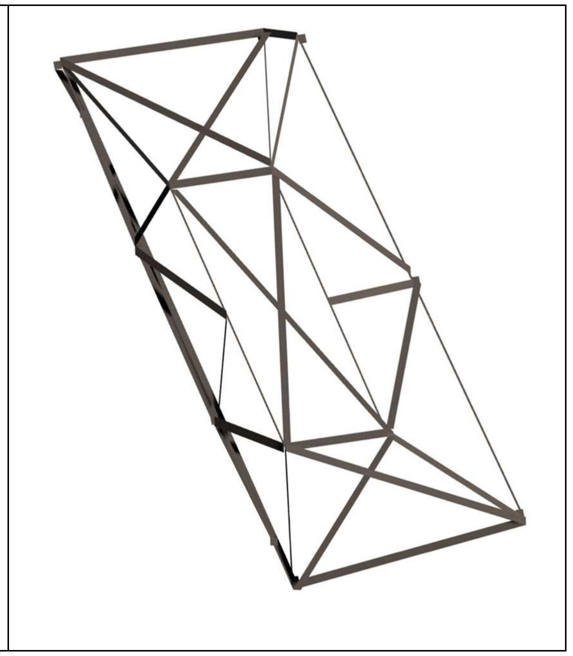


Roof truss

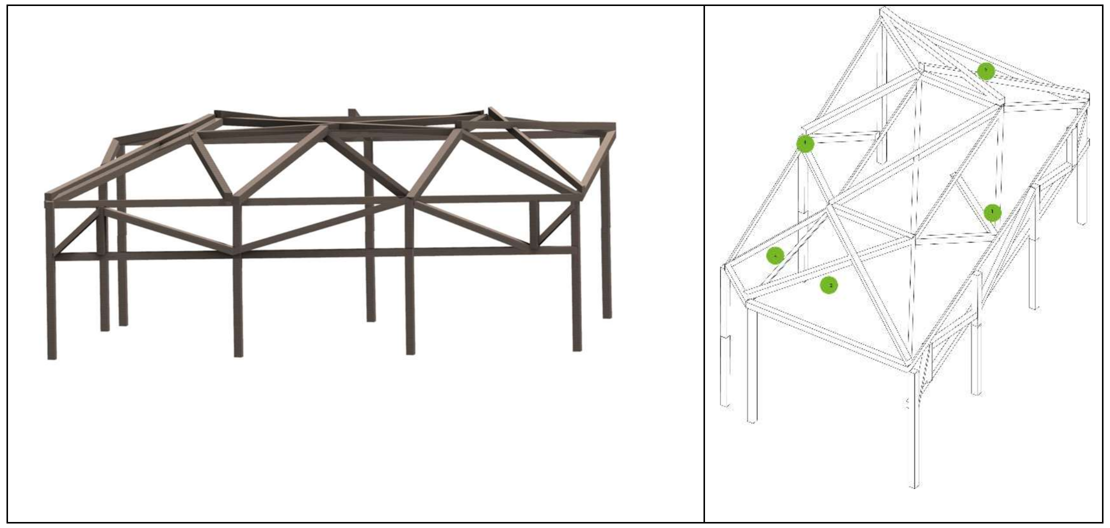
- Supports roof cladding, internal finishes, insulation.
- Glazing weight ignored and walls considered all solid for simplicity and to be conservative.

Calculations are for a part of the roof area then applied to the whole structure. This part is the gallery space east wing roof. Images below show the plan view of the roof. This is taken as a modular part of the whole roof to calculate the loads and size the truss, and then extrapolate this for the whole roof.

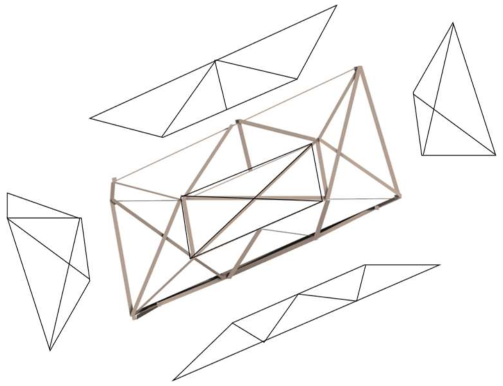


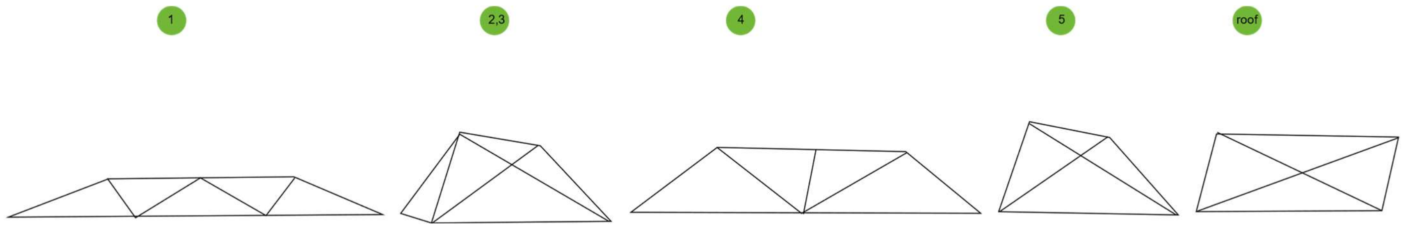


These images show an elevation and isometric of the truss structure with the 5 green labels indicating the 5 faces of the pitched roof for which the trusses are considered below.



Roof truss broken down into 5 faces to find load paths in each truss.

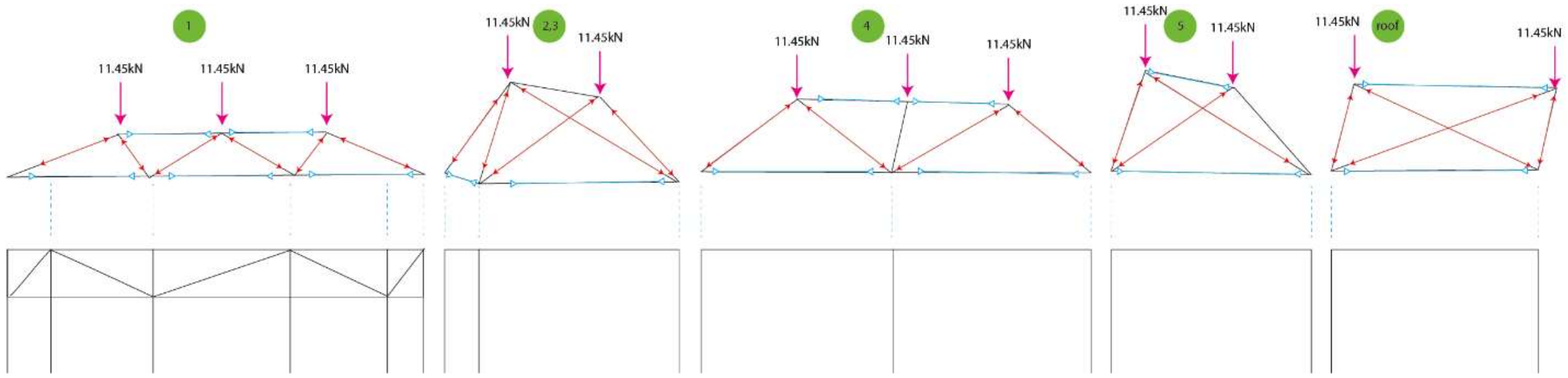




Cut Roofing Timbers & Sarking

- To accommodate increased roof insulation and more interior space= roof timbers assumed as being 45 x 200mm for a cut. This should also allow for most heavy weight roof coverings.
- The length of timber required for these elements per square metres of roof coverage has been assessed at 5.42 m /m².
- One cubic metre of softwood =5.4 kg each.
- Thus the weight of the roof timbers is 5.42 x 5,4* 200m^2 roof area = 5854 kg. *9.8/1000=57kN
- To this it is recommended that at least 9mm OSB3 roof sarking should be added.
- Therefore, assuming a requirement of circa 1.5m /m² plan area and a weight of, 7 kg/m² (including breather membrane and counter batten, nails, etc.) a self-weight of 1.5 x 7kg = 10.5 kg/m², x 140m^2 plan area =1470 kg. To convert to kN this is *9.8/1000 =14.4 kN
- This leads to the combined roof weight for timbers and OSB3 sarking = 71.4kN
- Snow load= 0.33kN/m^2 * 200m^2= 66kN. This is supported by the roof truss also.
- Total = 137.4kN over 12 point supports of the roof truss = 11.45kN point load on each point, assuming even distribution of vertical load.

11.45kN load on each of the 12 support points of the truss



Buckling:

- Pi^2 EI/ L^2
- Maximum roof truss length = 9.3m
- 0.45 0.25 cross section
- I =0.00059
- E glulam = 13.5 GPa
- Critical Buckling load= 909 kN critical load per column

The load is well below this therefore the columns will not buckle under this load.

Load of roof truss on columns:

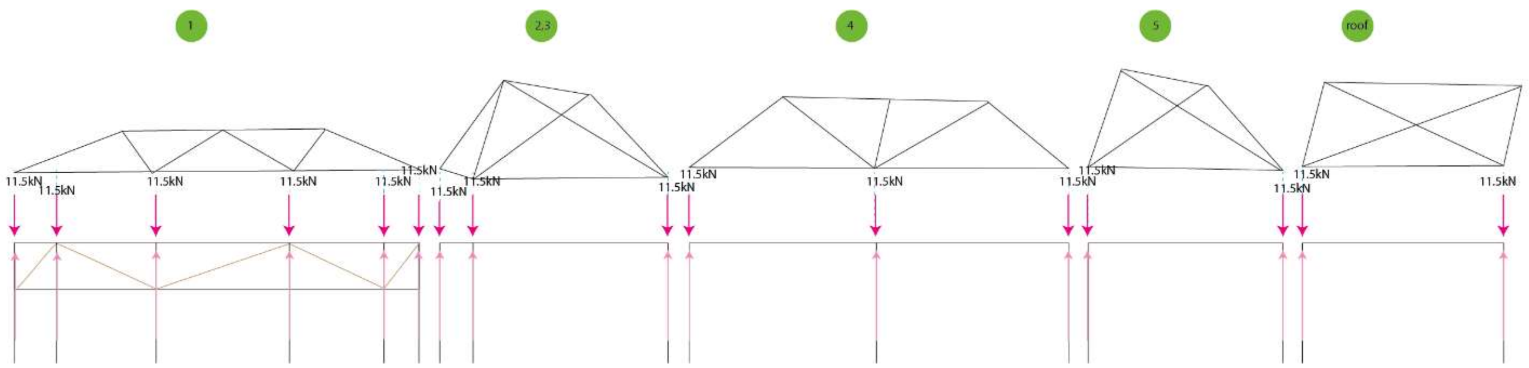
Load on roof truss =Previously found snow and cladding load= 137.4kN + beam self-weight.

Assuming glulam beam option 1 with strength 25 MPa with self-weight 0.41895 kN/m

Volume of truss 6.4m^3 with glulam beam density 380kg/m^2= 23.8 kN self-weight load of timber beams.

Total load on roof = 23.8 + 137.4= 161.2kN

On 14 points = 11.5kN point load on each.

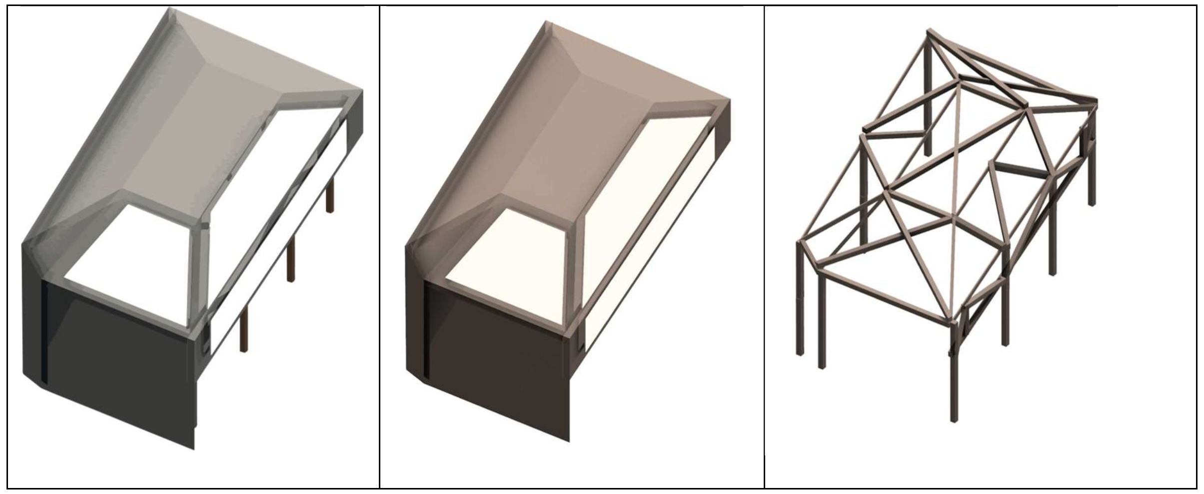


Buckling:

- Pi^2 EI/ L^2
- Maximum roof truss length = 6m
- 0.45 0.25 cross section
- I =0.00059
- E = 13.5 GPa

Critical Buckling load= 2183 kN critical load per column.

Roof Truss image



1. Overall view, 2. cladding and glazing, 3. internal truss and column structure

Gabions load:

Compressive strength 500kPa from Limit State software.

Self-weight 1390 kg/m^3 from https://www.simetric.co.uk/

1390 kg/m^3 *3m storey height* 55m elevation length* 1m depth= 2247.63kN

Total vertical load

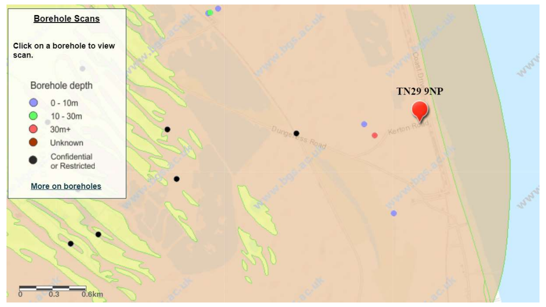
Therefore, the overall vertical load of the structure going down to the ground is

- 17782.95 kN from the timber structure +
- 161.2kN of roof structure +
- 2247.6kN of gabions

= 20191.75kN ~ 20.1MN

Soil

Borehole data from Denge Beach, Lydd, Sample from basal clayey siltstone



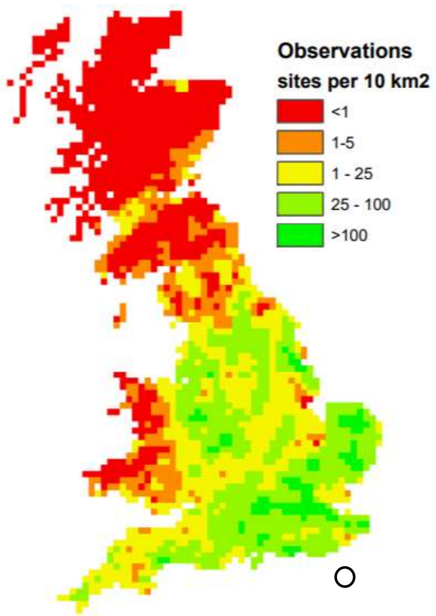
Layers of soil based on borehole from the British geological survey:
Therefore, the soil type relevant to the project is gravel and bands of sands, where the building will rest, and this is what will take the load of the building.

Soil bearing capacity based on BS 8004: 1986: Non cohesive soils sand and gravel 600 kN/m^2

TYPE	THICKNESS (M)	DEPTH (M)	LEVEL (M.O.D)
GRAVEL + BANDS OF SAND	6	6	-1.33
GREY SAND	4.5	10.5	-5.83
DARK GREENSAND	23	33.5	-28.83
CLAY WITH GRAVEL	2.15	35.65	-30.98
GREY CLAY WITH LIGHT GREY CLAYEY SILTSTONE	1.35	37	-32.33
LIGHT GREY CLAYEY SILTSTONE	0.6	37.6	-32.93

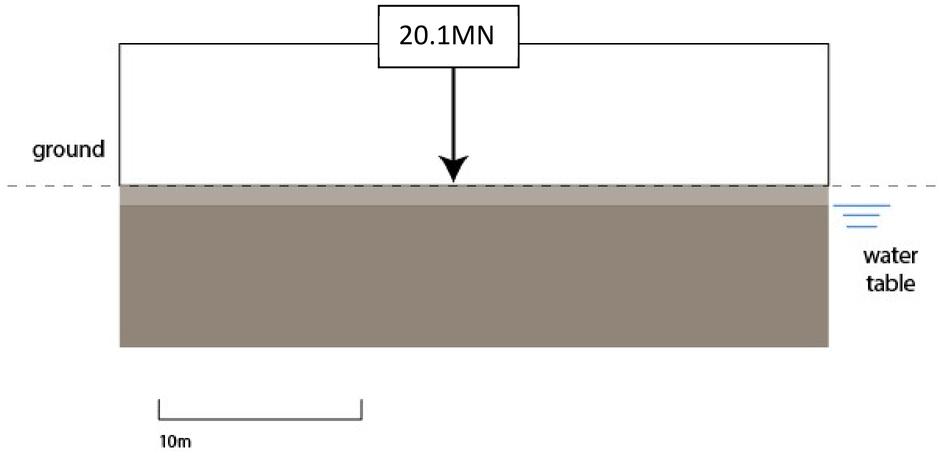
Site type

Brownfield site with previous quarry nearby, therefore it's important to ensure the site is safe, accessible and there is no risk from nearby water.



British Geological Survey National Depth to Groundwater Dataset, water level 1-25m below ground level.

Most conservative approach: 1m



Total vertical load = 20.1MN

20.1MN/ 80 columns and gabions

Only a third of the gabion area is included as it only covers around a quarter of the perimeter.

20.1MN/ [(80*0.1m*0.1m) + (55m*1m/4)]= 20100kN/[0.8+55/4 m^2]= 1381 kPa pressure on ground from the building.

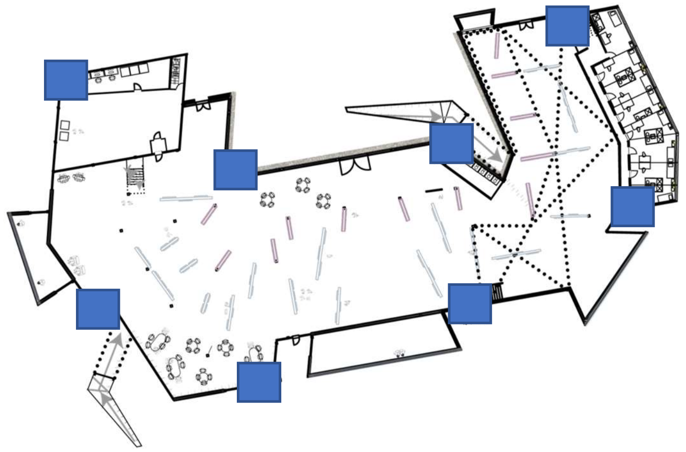
1.4 factor of safety based on Eurocode 7 for geotechnical considerations= **1934 kPa**

Soil strength 600kPa, therefore an extra footing is required.

Concrete unit weight 23.5 kN/m^3 and 1m depth = 52.875 kN self-weight for a 1.5 m^2 foundation.

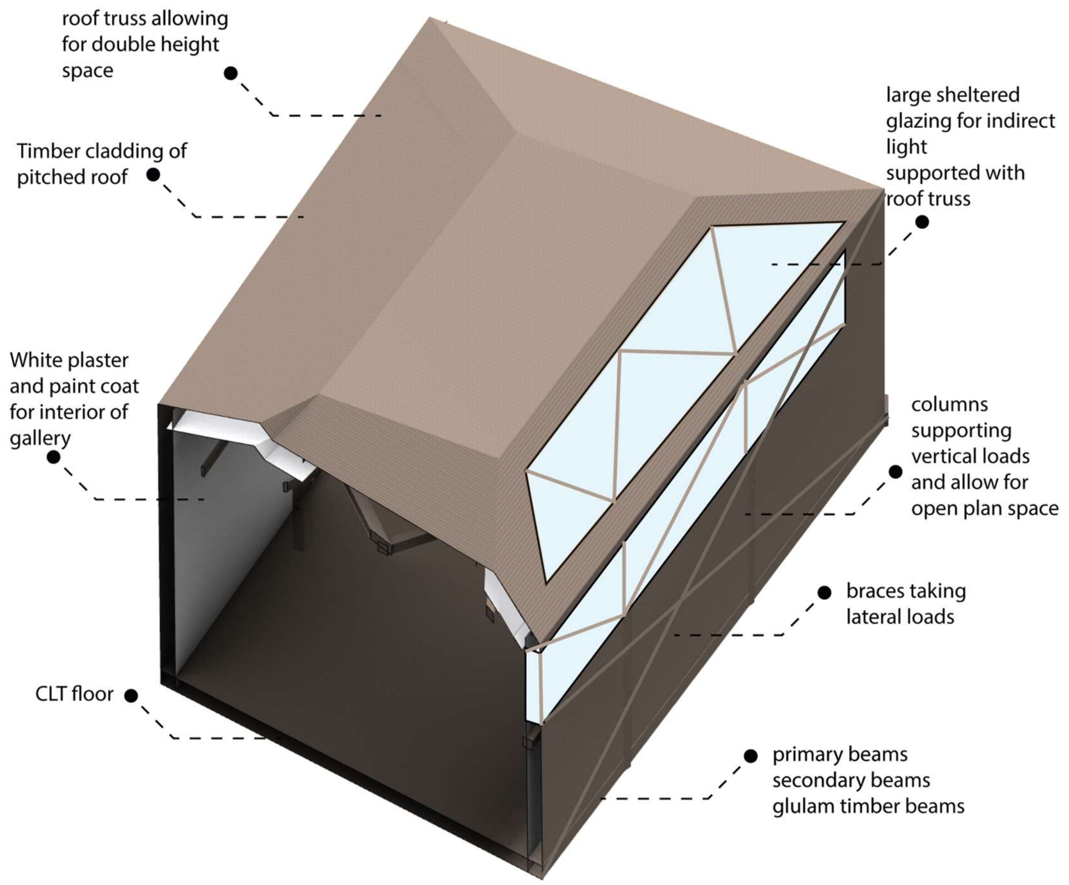
1934 kPa/8 pad foundations = 242 kPa each + 52.875 kN concrete self-weight= 295 kPa .

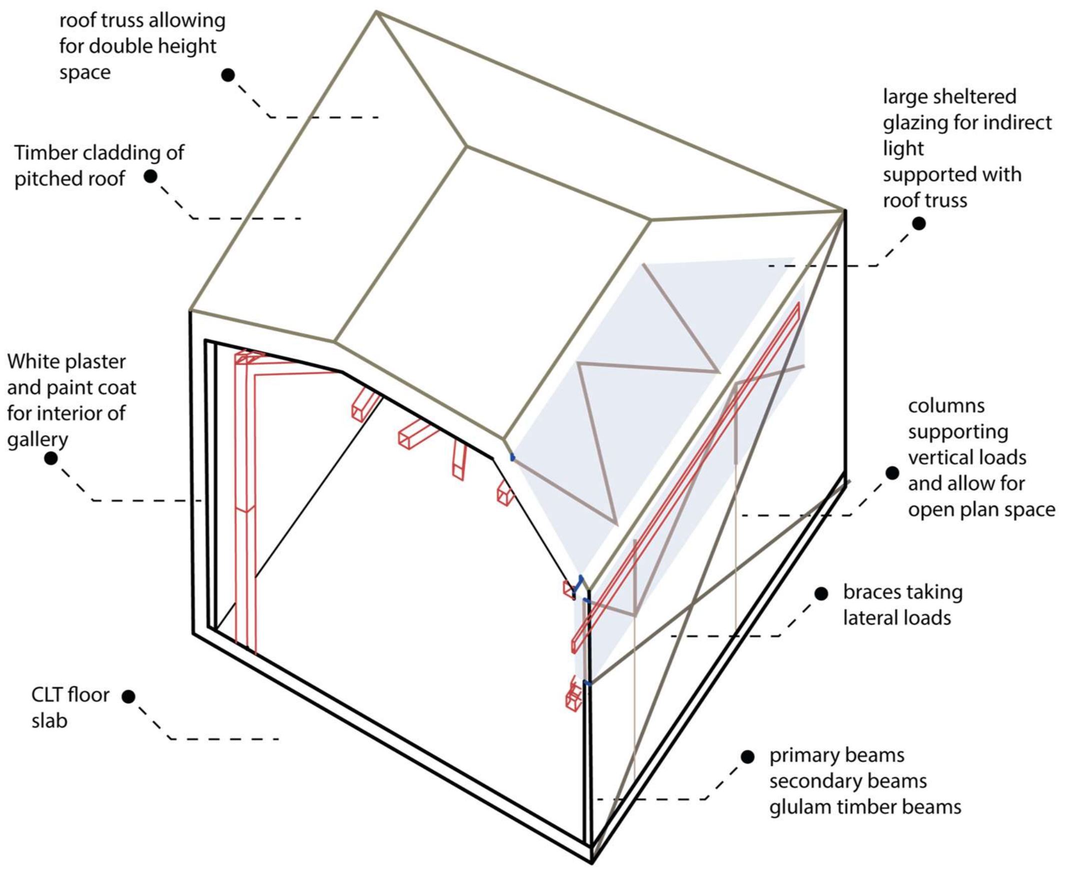
Concrete strength 230 kPa, each pad bearing capacity = 230 * 1.5 * 1.5 = 517.5 kPa



Structural section

Section of double height gallery space.





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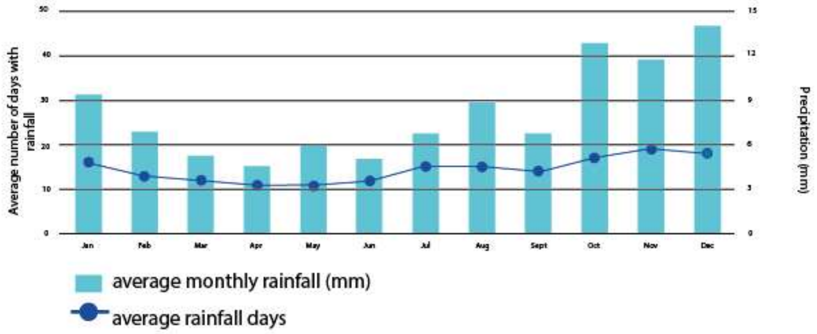
Part 2

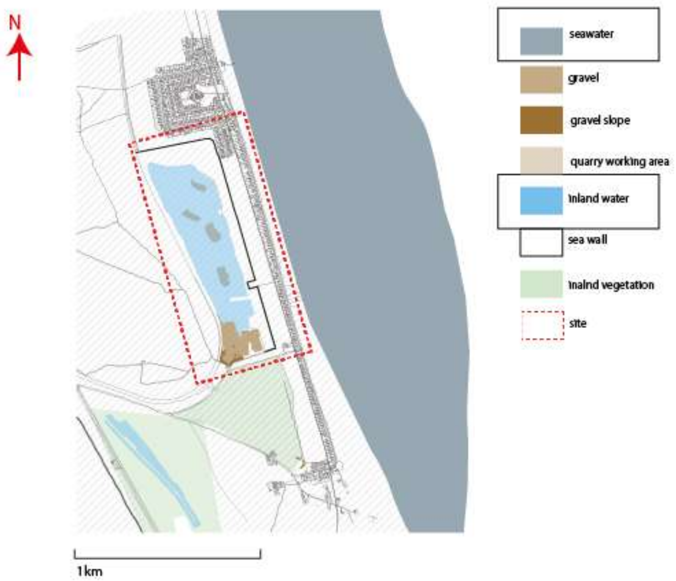
Environmental Considerations

Initial research: climate

A. Rainfall



Site plan highlighting water bodies, high rainfall may result in rise in water levels/ hazardous situation



Conclusions:

- October to December period with high rainfall, low risk of flooding, higher inland water levels.
- This creates interesting photography opportunities of water bodies especially from balcony areas and views out to water.

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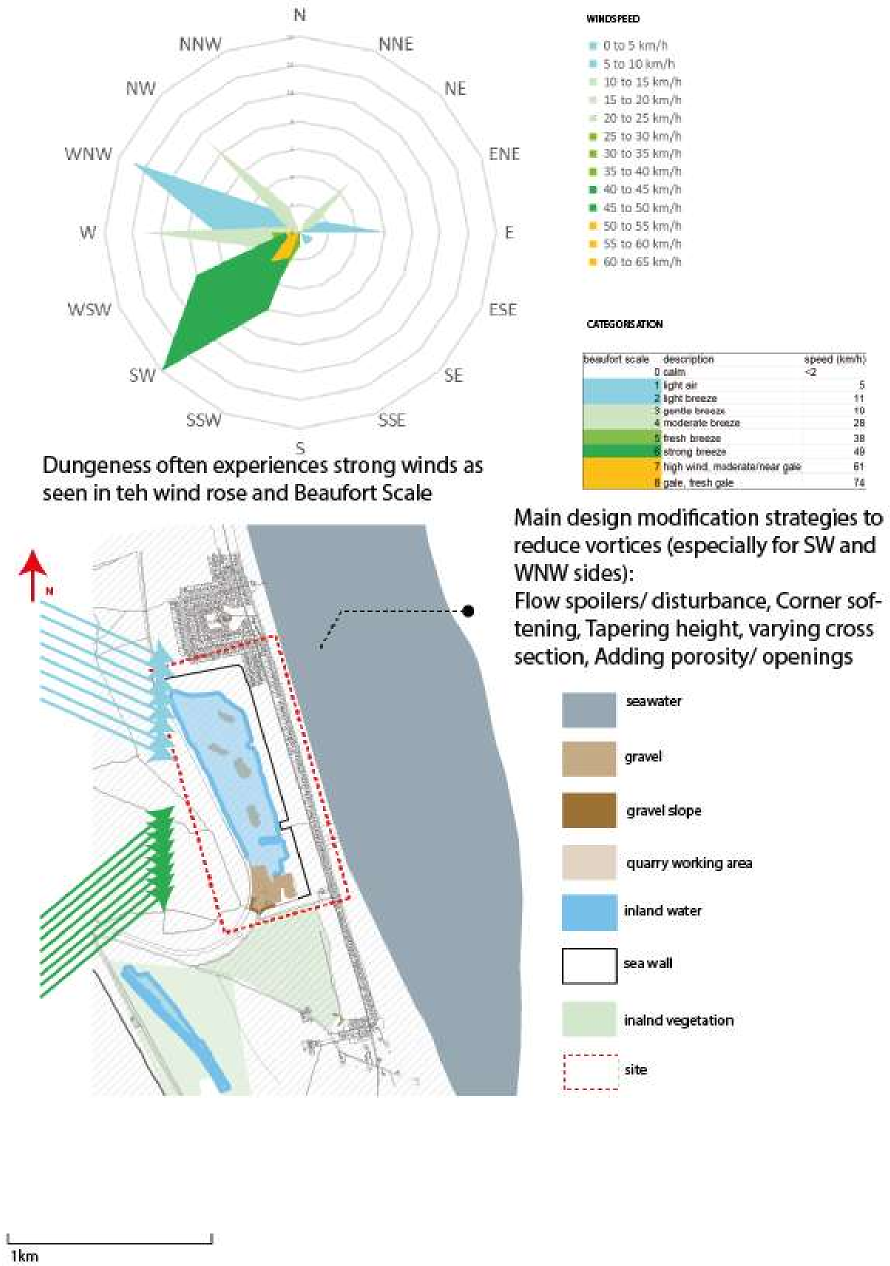
B. Wind



Conclusions:

- Design adjustments to SW and NNW facades needed in particular to reduce wind loads
- Utilise high winds in SW and NNW facades for drying room and extract chemical fumes from developing room

C. Sun

Sun Shading Charts

4 orientations of building, dec-jun and jun-dec graphs showing times of sunlight exposure and times to frame key views for the photographers.

Sun path Investigation Methodology and source: use December to June sun charts from Climate Consultant using location weather file, and specify 4 facade orientations to observe sunpath (180 degree view assumed from flat window) Observations and Conclusions: anticipate sunlight exposure hours and altitudes from 4 provisionary facades at 4 compass points, noting that the south-facing window receives most sunlight throughout the day, East receives in beginning of day, West in end part of day, and North receives very little sunlight throughout the day. This will be used to inform room function/ purpose assignment in building based on sunlight needs and activities.

Dec to Jun sun charts, showing bearing angle on x axis and sun altitude angle on y axis (0 to 90 degrees being directly above), with window view frame shaded in green, and framed on the right column in green Months are the 6 different curve paths, and times of day indicated in the perpendicular dashed lines in blue (not accounting for daylight savings in summer)

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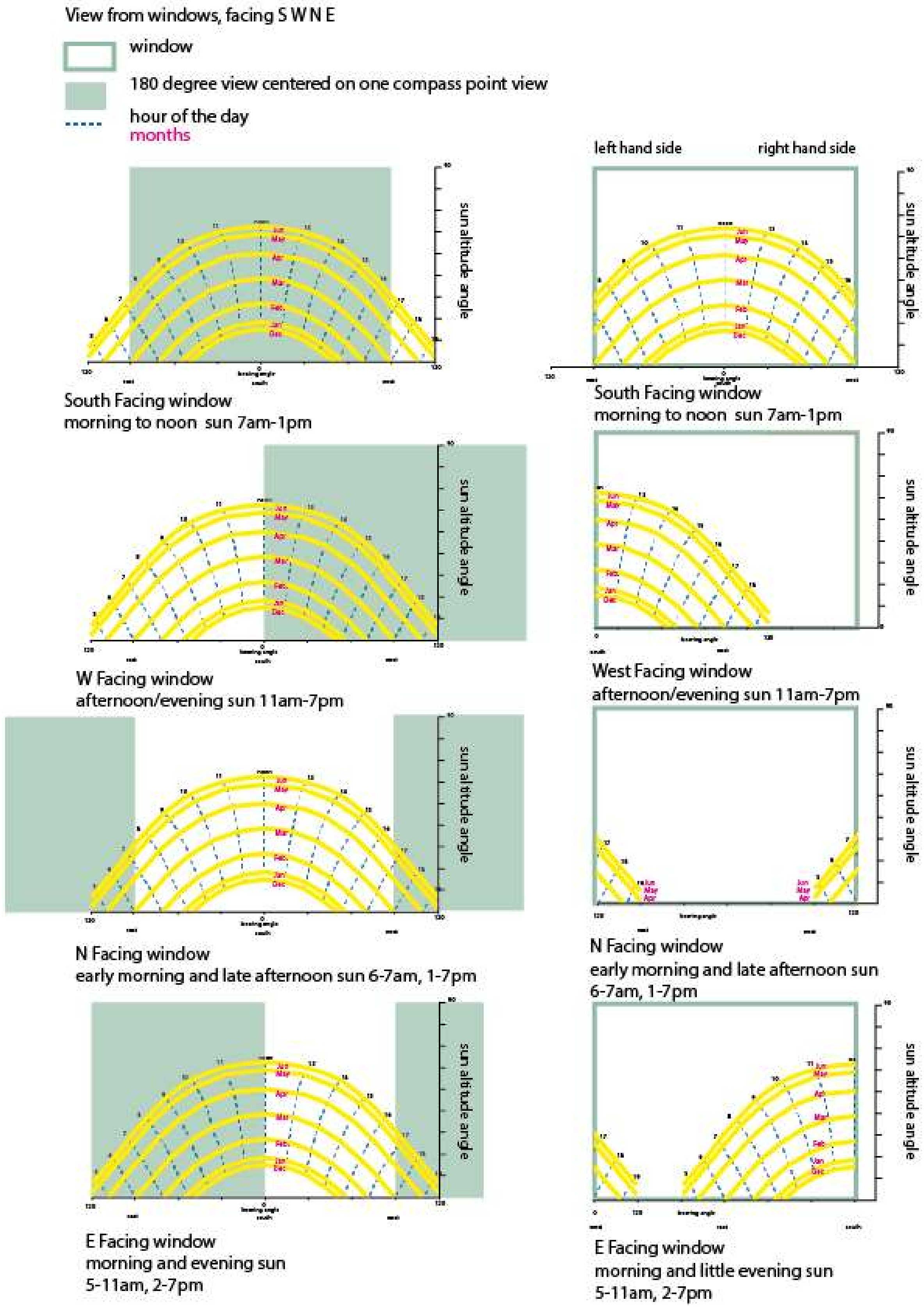
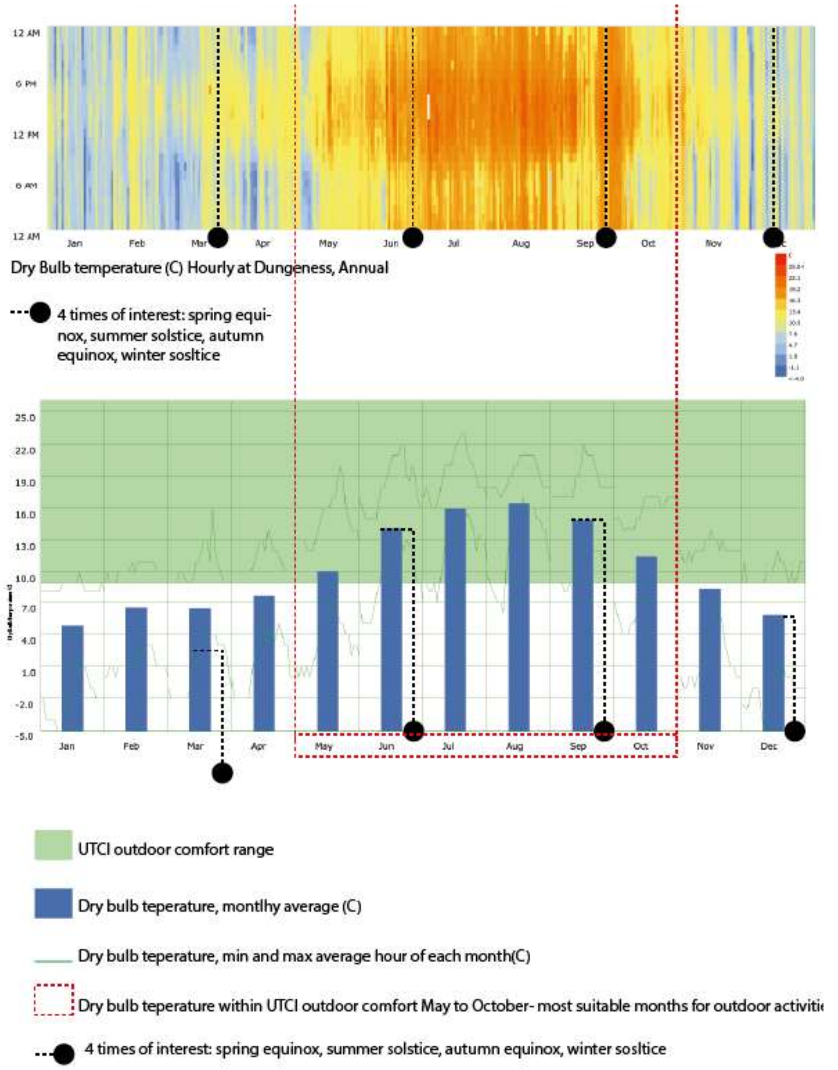


D. Temperature



Conclusions:

- Free-running period from May-Oct Days of interest within this period: Summer Solstice and Autumn equinox
- opportunities for natural ventilation and openings
- opportunities for extensive use of balconies, ramps and outdoor space to observe and capture the landscape
- suitable outdoor summer temperatures allows for open interior/exterior spaces due to, therefore opportunity for maximum interaction with landscape and seamless flow between interior and exterior spaces

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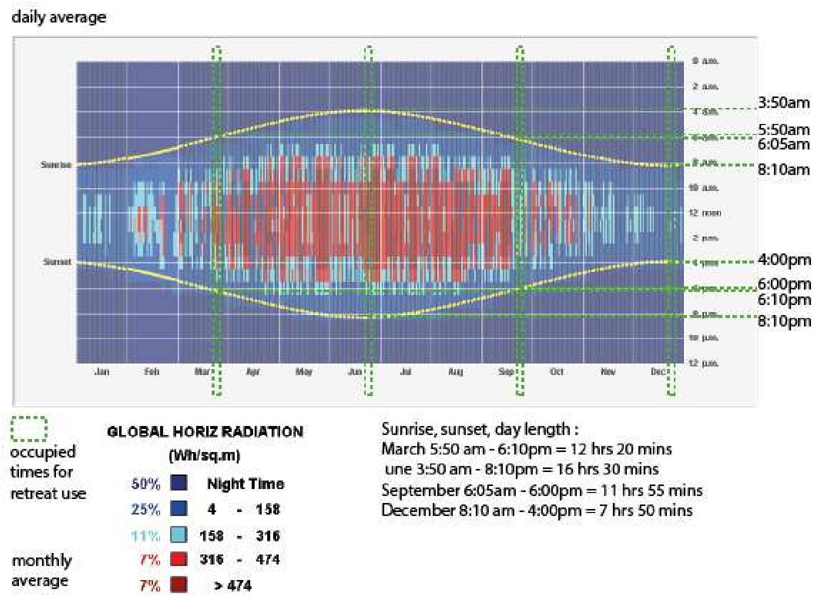
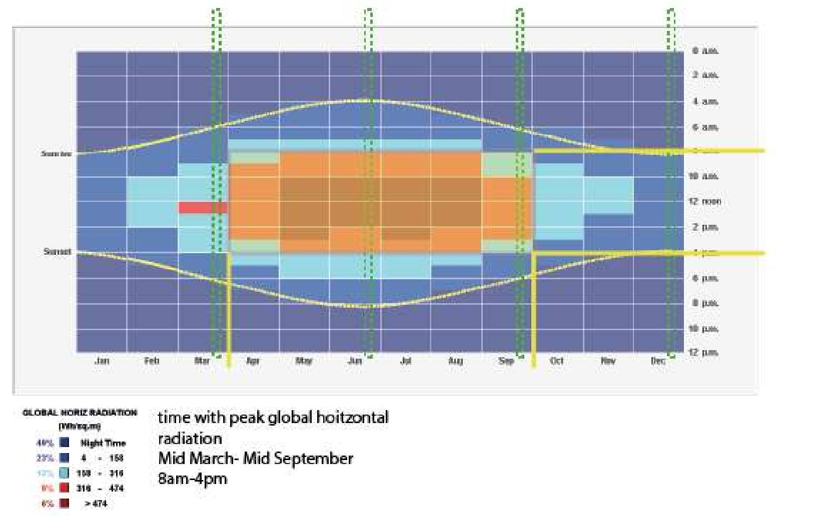
E. Visibility

Timetable plot of Global Horizontal Illumination: total visible light that falls on a horizontal surface from the entire sky vault plus Direct Normal Illumination from the sun. The units are in lux (lumens per square meter). This research shows the changes in day length and illumination, and this will affect the routine and use of the spaces as well as the photographers' view to the landscape. For example, very long days in summer with high illumination will mean photography can take place from as early as 4am until after 8pm. The occupancy behaviour and requirements will change, compared to a very short daylight hours day in winter.





- summer solstice: long photography day and acute sun angles, interesting shadows, colours and and reflections
- autumn equinox: shorter photography day, interesting symmetry of light conditions

F. Light colour

Climate analysis: Coloured sky visualisation on 4 key dates of interest from the 4 seasons Using Cylindrical projection- an unrolled rectangular map of the sky

Objectives: Observe different light quality and sky colour across the 4 key dates for the retreat: spring and autumn equinoxes, summer and winter solstices Observations: significant sun altitude variations, with it being highest in the summer equinox resulting in a bright, blue, uniform sky. Lowest altitude in winter with amber hue. Similar view and colour property in equinoxes.

Outcome: insight into seasonal changes in sky colour and light properties, e.g. same room will receive high altitude sun and white daylight in June, and low altitude sun with deep shadows and orange-tinted light in December.

Conclusions: able to predict internal visual atmosphere and properties for daylit rooms across the 4 key dates, this will dictate activities/ use/ schedules for each season depending on required light quantity and quality in each space/ for each activity and provides an interesting photography opportunity for the community.

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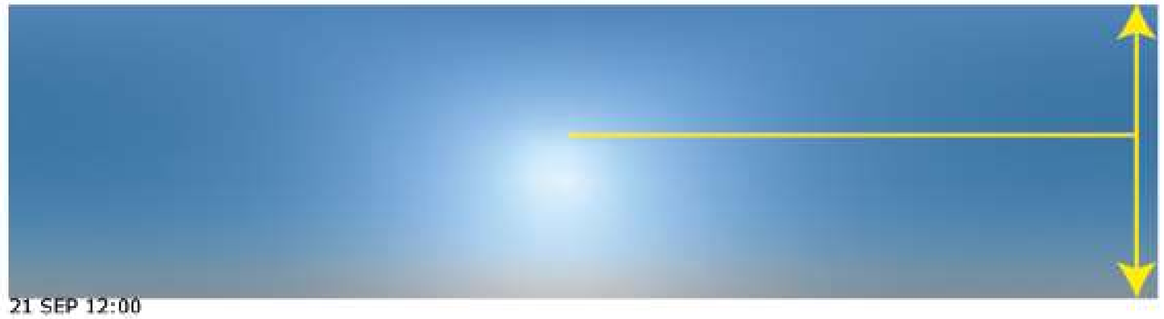
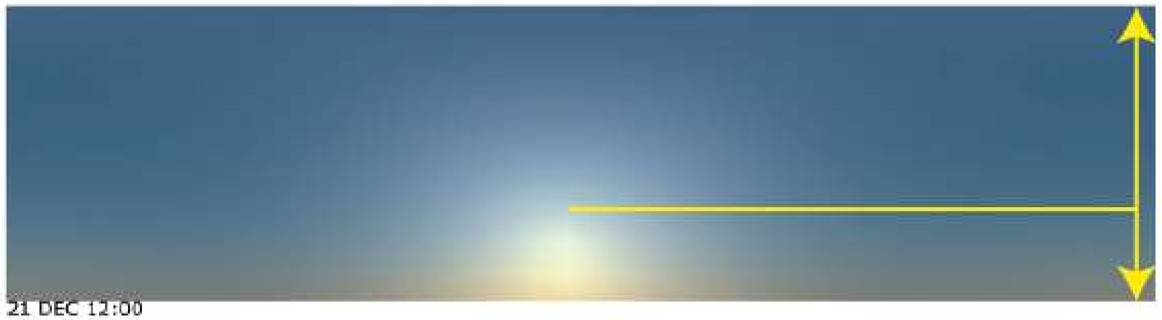
21 MAR 12:00

perceived sun altitude

21 JUN 12:00



21 SEP 12:00



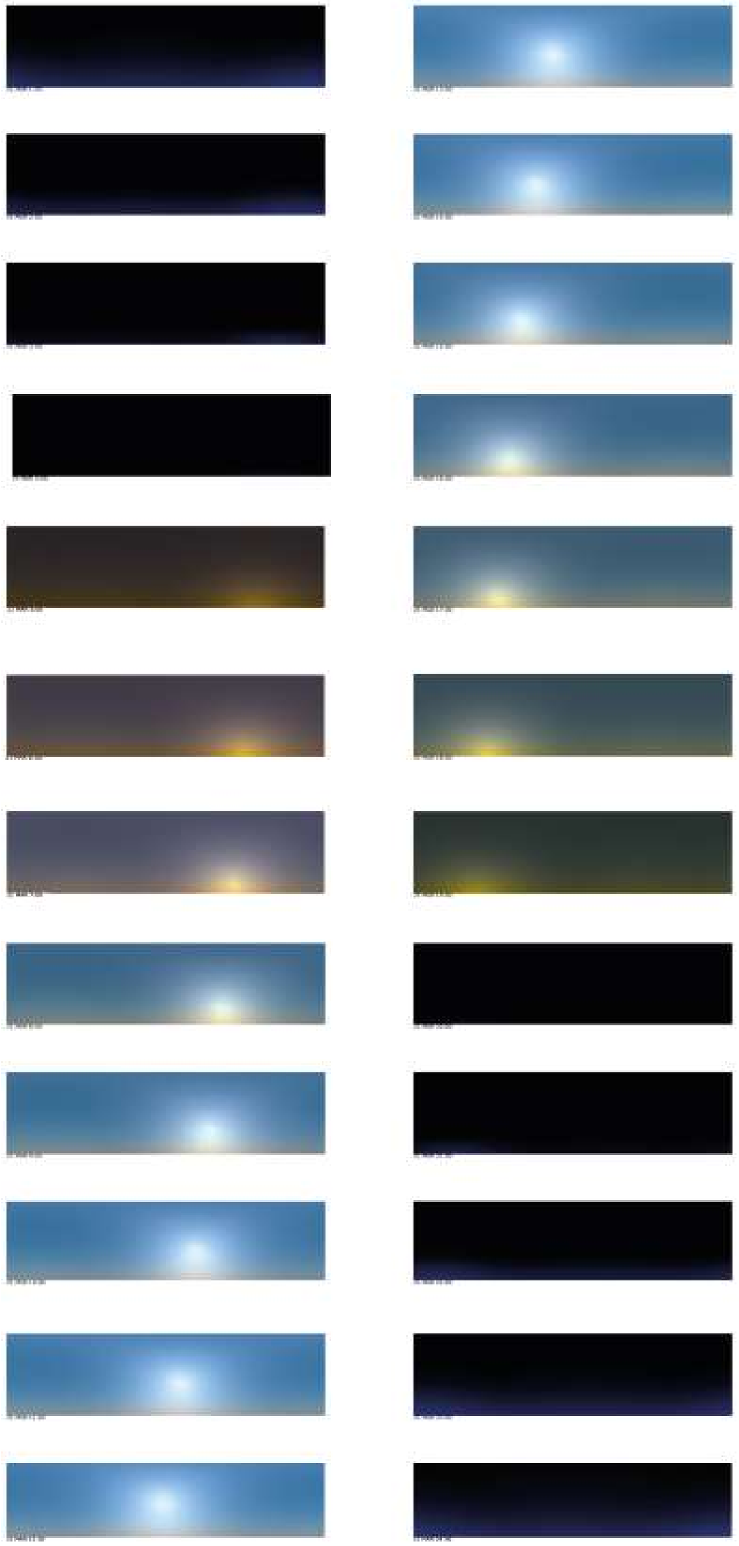
21 DEC 12:00

Coloured sky visualisation for a 24 hour period

Objectives: observe colour quality of light over one typical day, (spring equinox chosen)

Observations: range of colours; from purple to yellow to blue to orange hues. Also very interesting symmetry observed throughout a day

Outcome: insight into colour tone, gained more context on anticipated internal atmosphere based on external light colour and quality. Link to inventory, adapt schedules/ use/ activities/ in room based on this, e.g. private living spaces east facing to receive morning hue, and communal spaces west facing to receive amber evening hues.



Sundial

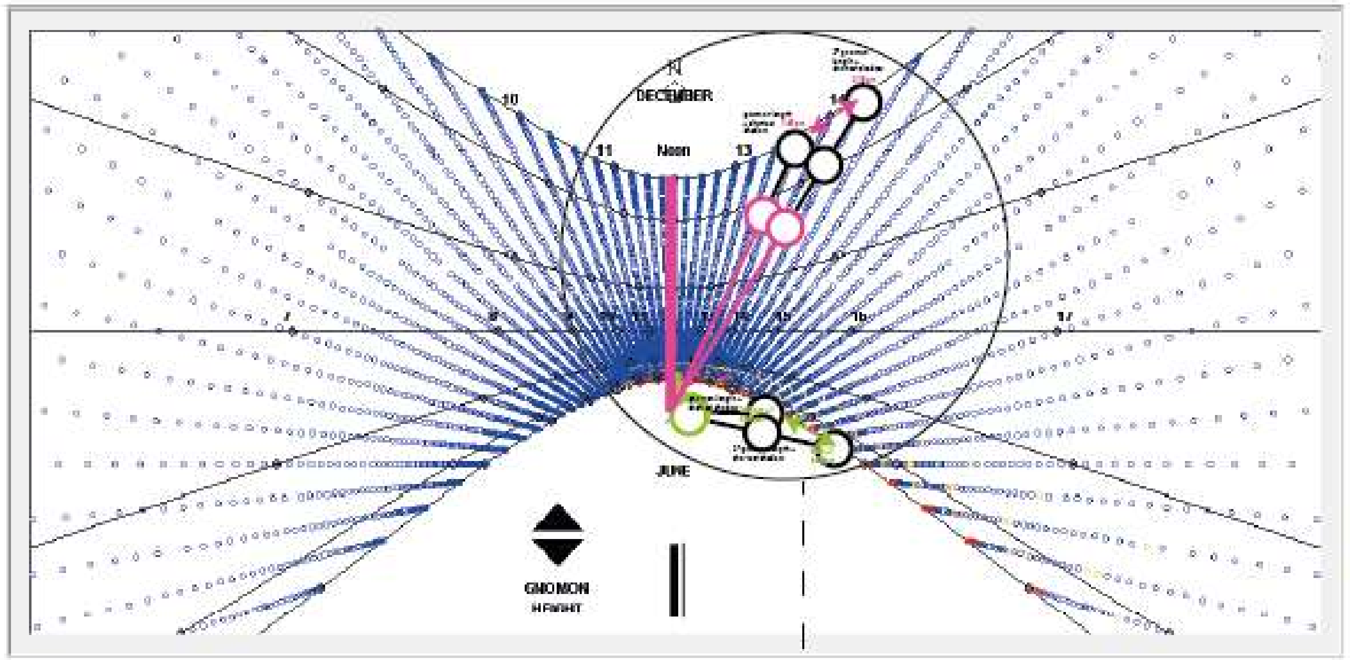
The gnomon is mounted vertically on the x shown as Gnomon Position. It shows in plan view the shadow cast by the gnomon for every 15 minutes during the year in coloured dots. Yellow dots indicate comfort conditions for dry bulb temperature and to prevent overheating windows should be fully shaded wherever there are red or yellow dots Red dots indicate overheat conditions for dry bulb temperature Blue dots indicate underheat conditions for dry bulb temperatures Ideally for passive heating the windows should be fully exposed wherever there are blue dots By locating something the height of the gnomon at the point indicated, this chart can be turned into a sun dial.

This study shows how sun and shadows activate the 5 prayer times and can be used to activate building activities in the art centre that can act as a sundial for the photography day, to direct photographers to move around it following the sun path and following the changing light colours.

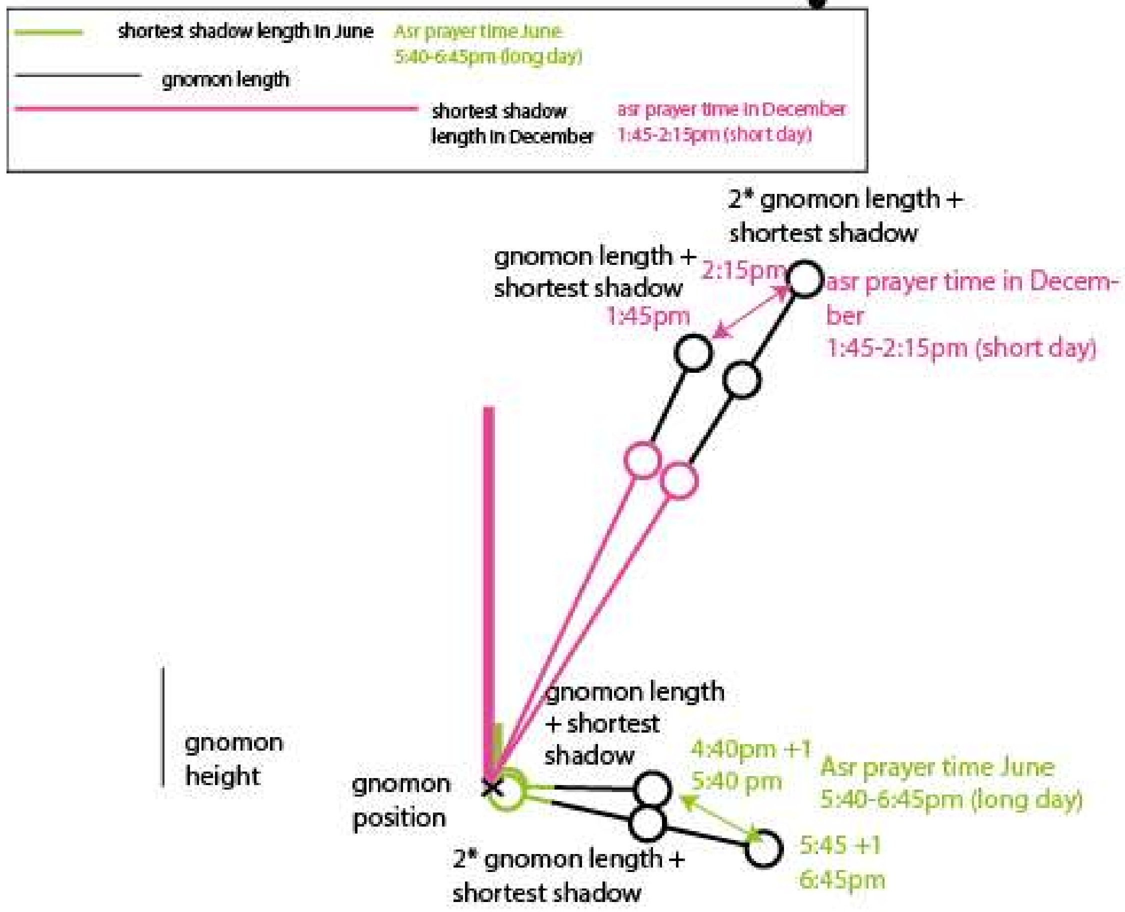
It also shows the link of the building as a sundial with its potential performance, and where there may be overheating or underheating. It indicates a strong case for north glazing and to avoid south glazing.

Vertical Sundial

Dec 21- Jun 21 Chart



Showing asr prayer times in June (green) and December (pink) shortest shdow length+gnomon length, shortest shdow length+2*gnomon length



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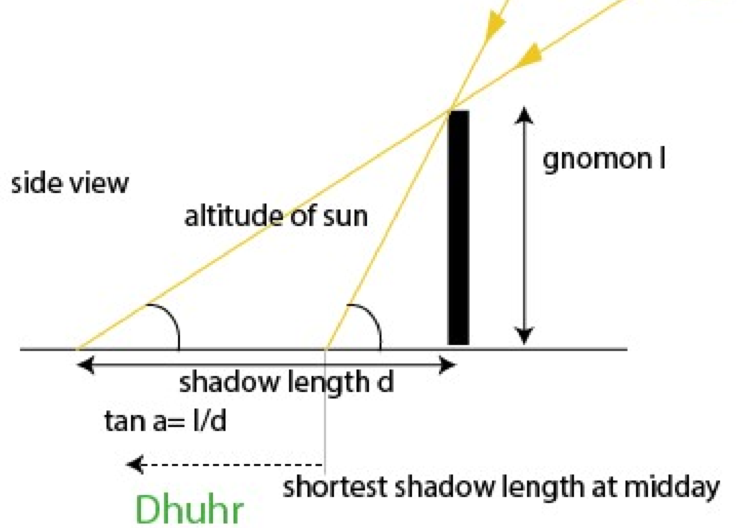
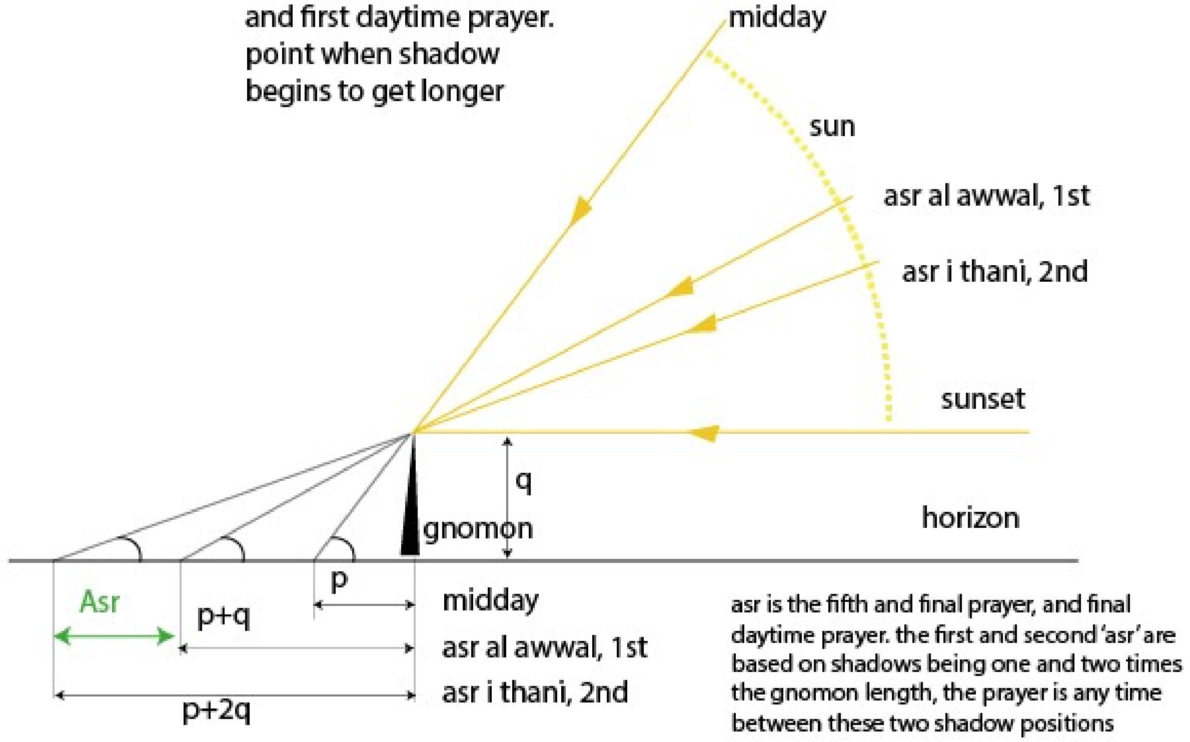
Prayer calculations
Sundial

This is a study of how the daytime prayers are calculated based on sun positions. This links to how my building can be used as a sundial based on sun and shadow positions. Following the sunpath in a day, the changes in angles and shadows is an indicator for a new activity and new light quality



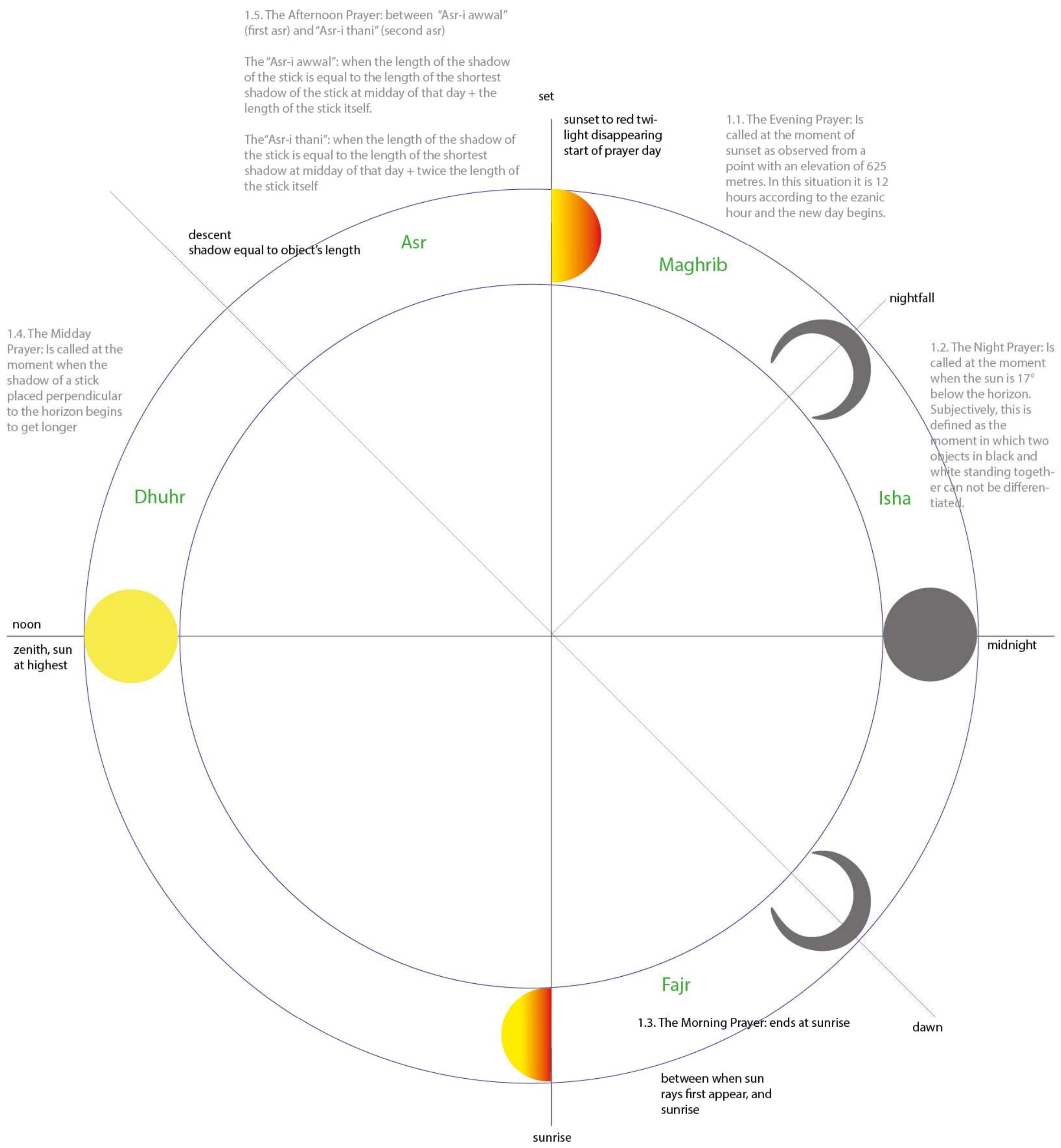
Duhr is the fourth prayer and first daytime prayer. point when shadow begins to get longer



Light quality

I use the prayer times to find the light quality at each prayer time in the day, as this is a main driver for the daily activities and is something my building is aiming to replicate and introduce.

Sun, moon and prayer times



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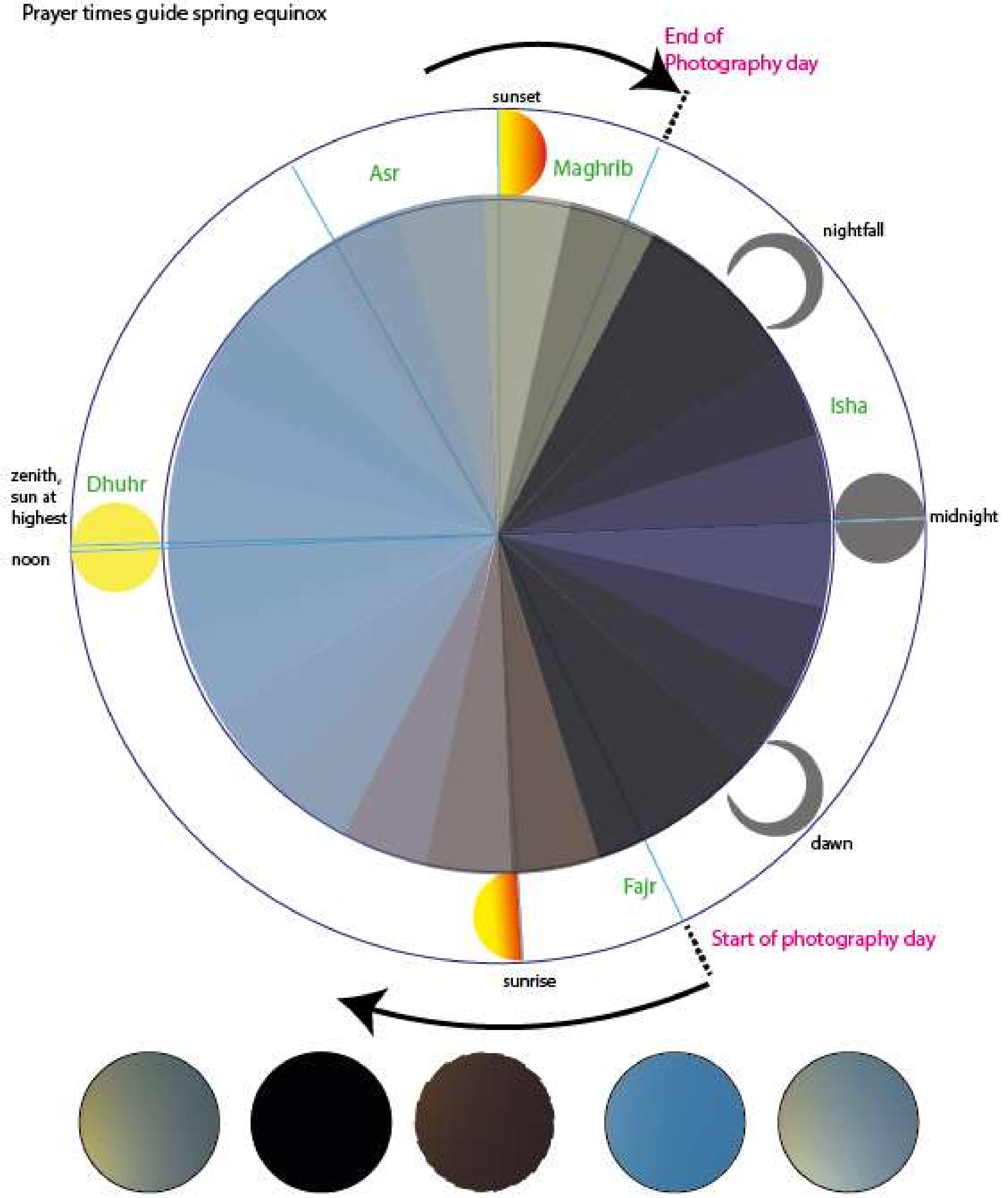
Time plot of Coloured sky visualisation 24 hours at Prayer Times Using a coloured sky visualisation and Cylindrical projection Objectives: demonstrate change in colour quality of light over one typical day, (spring equinox chosen) at 5 prayer times. Observations and Outcomes: insight into colour tone: range of colours; from purple to yellow to blue to orange hues.

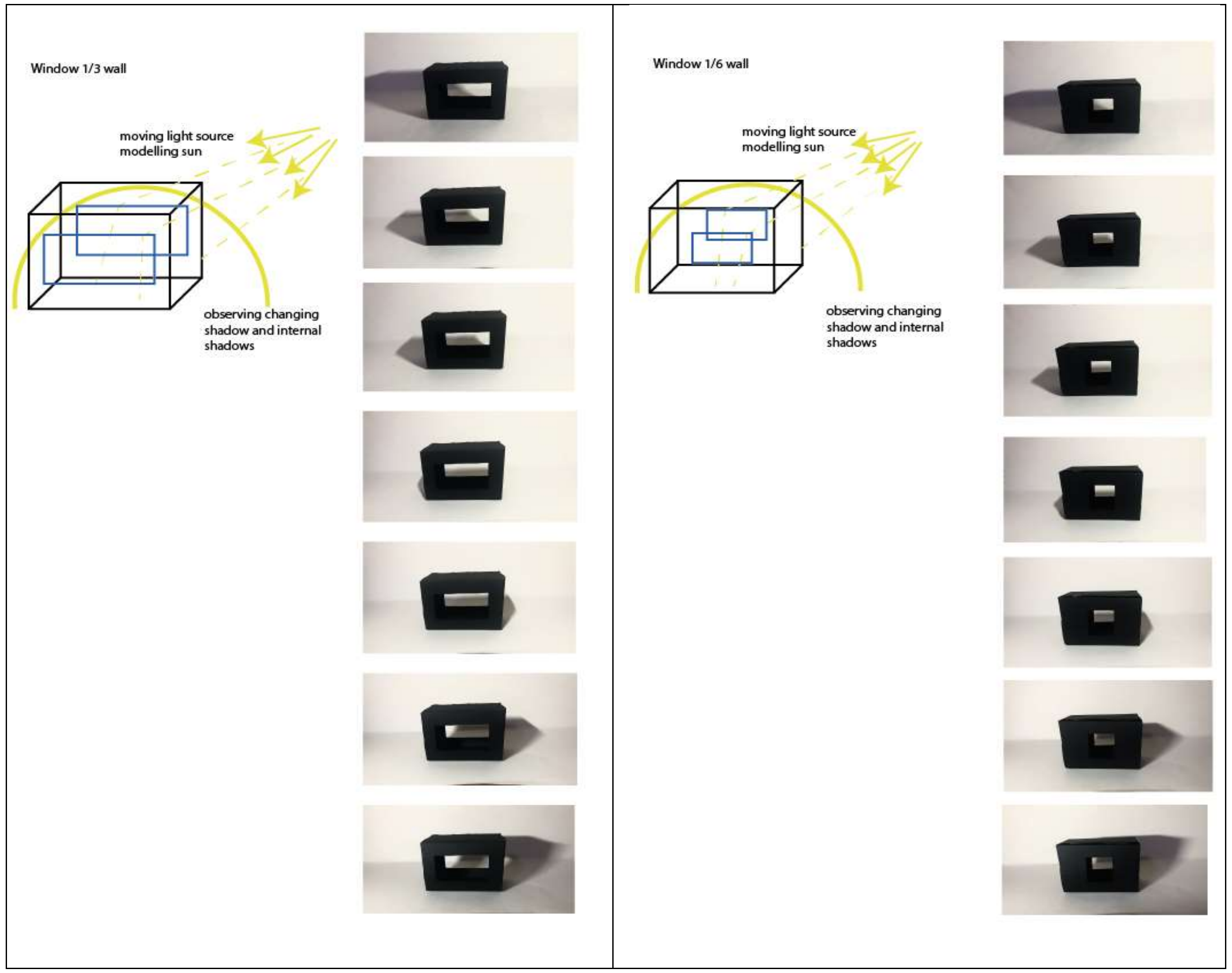
Prayer times guide spring equinox



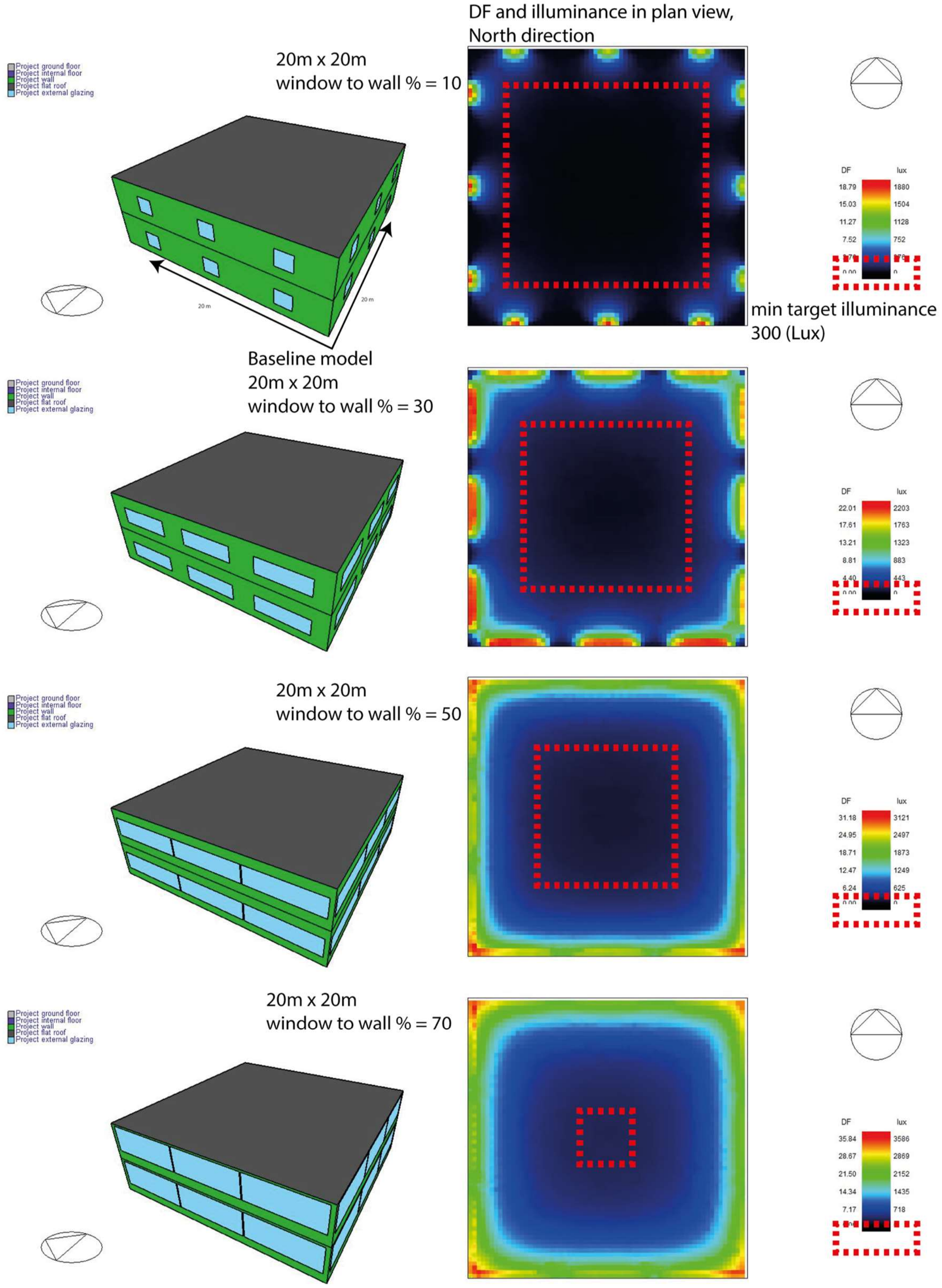
Light Quality at time of 5 Prayers on the spring equinox
Influences internal visual atmosphere
Building as a sundial: using this to plan for room design, layouts and orientation in building depending on activities.

Window: wall ratio, shoebox modelling

Observing changes in light and shadow characteristics while modelling sun path using lamp iteration 1 window 1/3 wall area, iteration 2: window 1/6 wall area. Impact of larger glazing ratio: deeper light penetration, less opaque shadows. Interesting for photographers to have a variety of glazing ratios and experience different light qualities.



DF simulation varying window to wall ratio



The red areas show the plan area with insufficient daylight. It is clear that larger windows have huge impact on the light of the space and is in line with my requirements for having a good internal visual environment, however this needs to be balanced with thermal performance.

Lighting

- Maximise daylight
- minimise the building's overall energy- minimise heat gain during the cooling season and heat loss during the heating season
- takes advantage of shading strategies and glazing technologies

Challenge for my building:

- use the changing colour of the light during the day
- good daylight
- little sunlight in the summer
- use the solar energy in winter

Principles used in building

- avoid south-facing windows and direct sunlight that contribute to heating
- North facing windows introduce daylight without heat gains of direct sunlight
- Use pitched roof skylights/light wells inspired by Kent's oast house vernacular
- Use light coloured interior surfaces for the gallery and living spaces to reflect more light and reduce the level of artificial lighting required
- Use horizontal shading to shade from low sun angles on the east façade
- Light shelf in central gallery space to reflect diffuse northern light for deeper plan penetration

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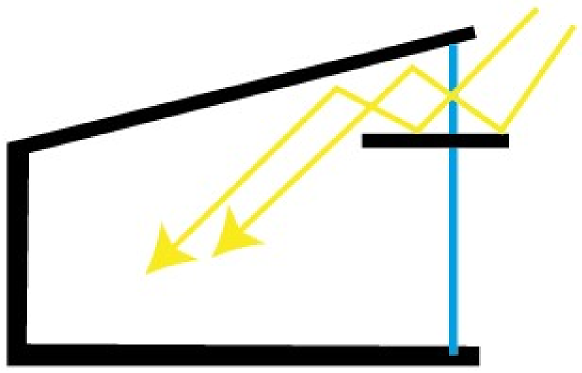
Some of these strategies are illustrated here:

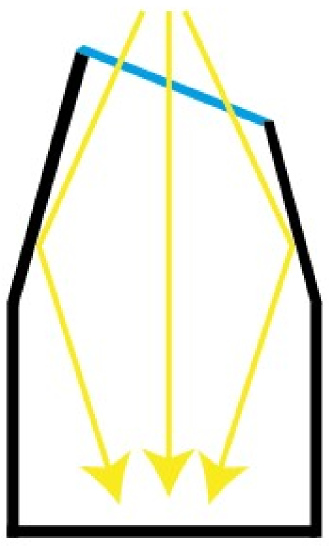
Light Shelf

Daylight penetration solution for deep plan



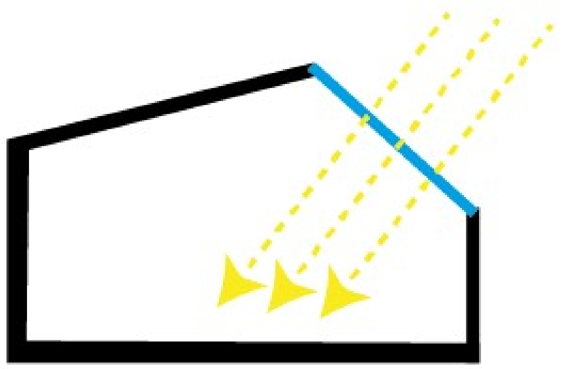
Light well, Kent Vernacular

Suitable for deep plan, focus on horizontal lighting



North Facing pitched sky-light, diffuse light

Large window area, cover facade



Visual performance simulation in gallery space

This modelling of the interior view of a gallery space over 4 time periods of the 4 seasons was used to show the different qualities of light from the same view over the course of the year. This is to simulate the atmosphere inside the gallery and how this may affect the way exhibits are perceived.

Requirements: avoid strong directional light and glare to allow for good visibility of exhibits and visual comfort.

Modelling: climate-based point in time image-based simulation with true and false colour rendering. A perez sky model based on hourly direct and diffuse radiation data is used: Direct 181 diffuse 300 Cd/m^2 showing luminous intensity per square metre from daylight.

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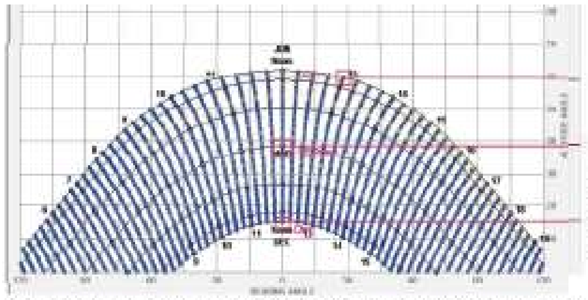
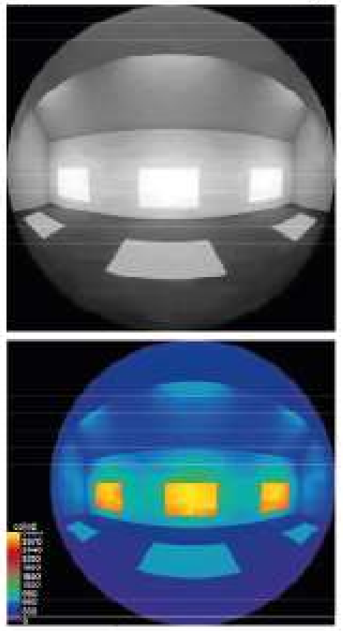


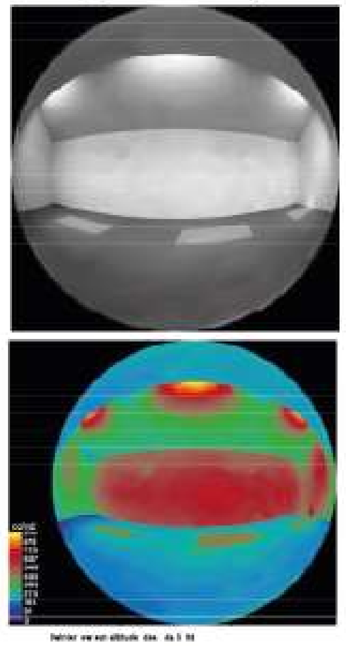
1 spring equinox 12pm
2 summer solstice 1pm
3 autumn equinox 1pm
4 winter solstice 12pm

sun positions derived from vertical sundial diagram at each of the 4 times

spring equinox, sun altitude around 40 degrees at noon

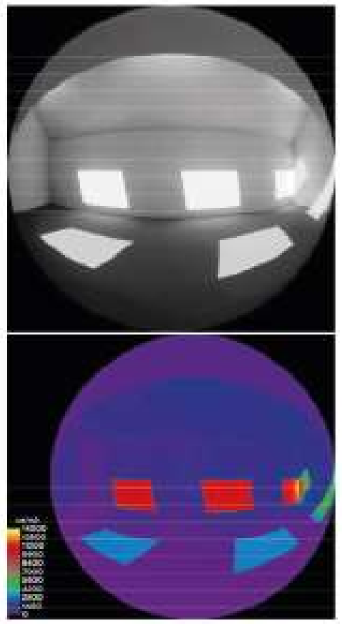


summer high sun altitude, diffuse light

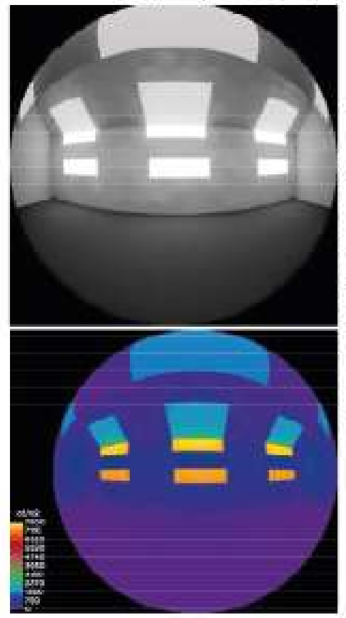


evenly lit room in summer indirect light good for exhibition spaces low glare and protecting artwork

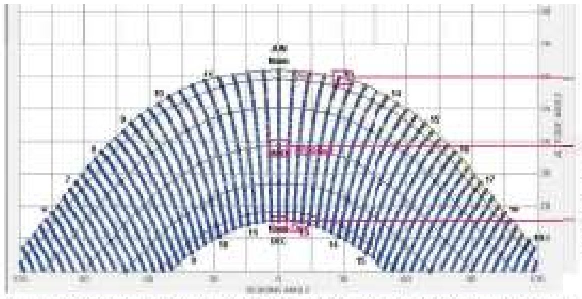
autumn equinox, sun altitude around 40 degrees at 1pm



winter, low sun angle, deep daylight penetration



low sun in winter leads to direct light, may damage artwork or be uncomforta-ble. Rethink orientation/ shading options



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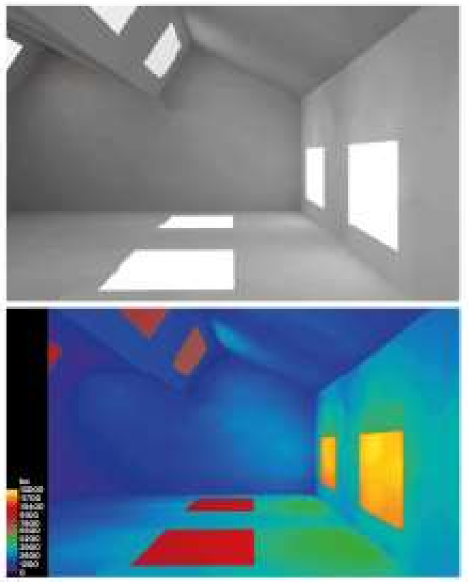

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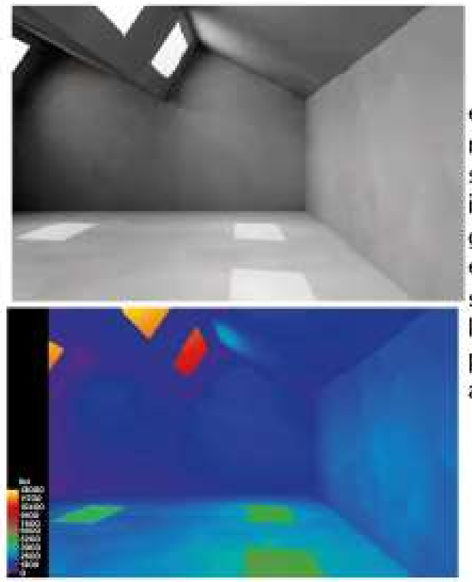

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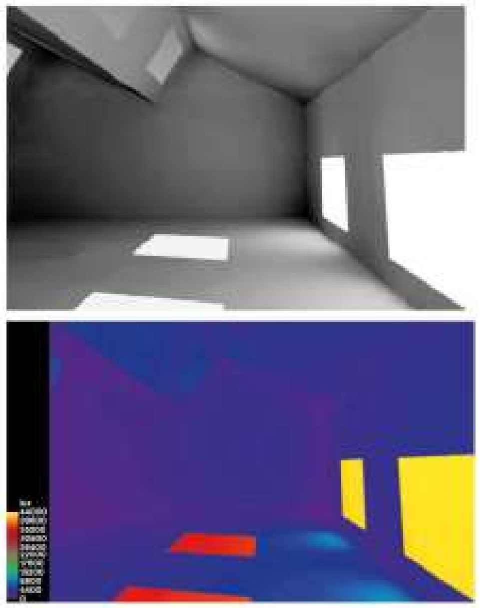
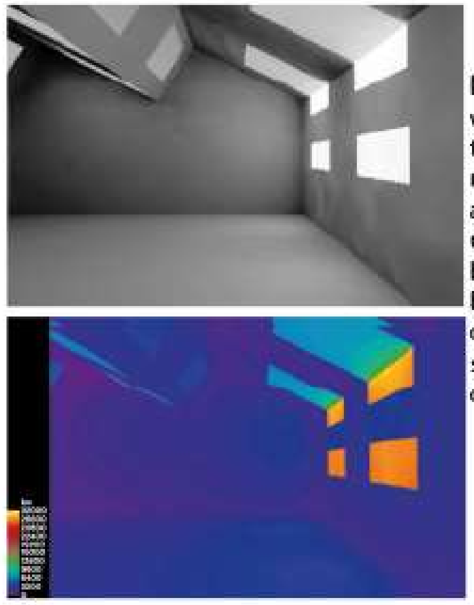


winter, low sun angle, deep daylight penetration



low sun in winter leads to direct light, may damage artwork or be uncomforta-ble. Rethink orientation/ shading options

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Passivhaus guidance:

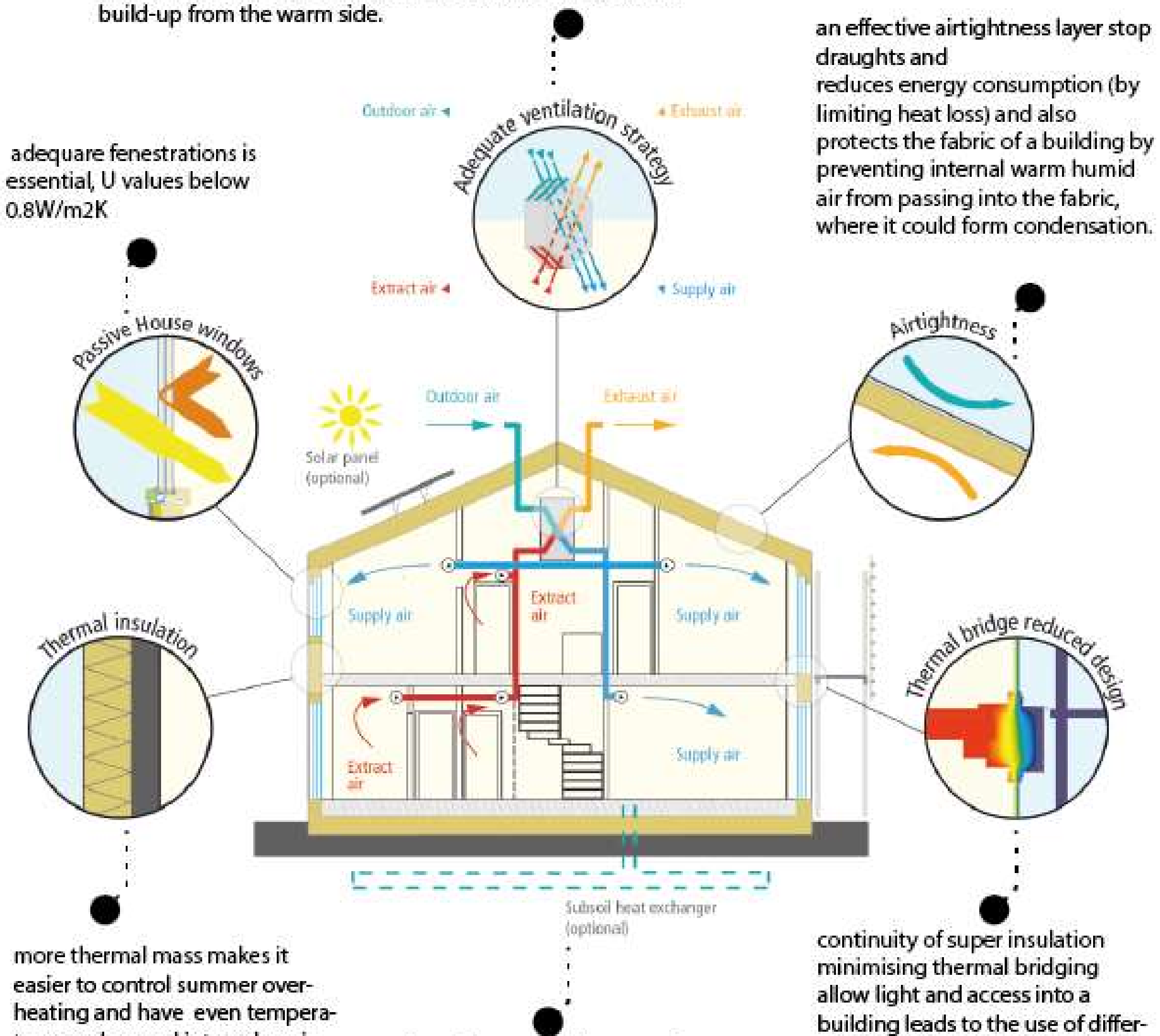
Maintaining airtightness: Passivhaus buildings need to achieve 0.6 air changes/ hour @ 50 Pascals, approximately 15 times more airtight than the present UK Building Regulation requirements.

To minimise this risk, a rule of thumb is for the airtightness layer to be within the first third of the insulation build-up from the warm side.

The airtightness strategy needs to include a continuous layer joining each of the fabric components, using an appropriate material robust enough to last the lifetime of a building

an effective airtightness layer stop draughts and reduces energy consumption (by limiting heat loss) and also protects the fabric of a building by preventing internal warm humid air from passing into the fabric, where it could form condensation.

adequare fenestrations is essential, U values below 0.8W/m2K



more thermal mass makes it easier to control summer over-heating and have even tempera-tures and a good internal envi-ronment over the changing seasons.
masonry or timber frame construction with a solid ground floor (usually concrete on top of insulation) is often used and is a good way to provide thermal mass

form-factor ratio, the area of exter-nal envelope through which heat will escape compared to the area of usable internal building area, 0.3 or less

Wall construction:
wall elements in Passivhaus buildings should aspire to: a U-val-ue of between 0.10 W/m2K to 0.15 W/m2K

continuity of super insulation minimising thermal bridging allow light and access into a building leads to the use of differ-ent materials with different ther-mal properties. Good design of each of these details to minimise the thermal loss is crucial both to keep heating demand down and to avoid cold spots where conden-sation might form.

Minimising thermal bypass: A breather membrane layer on the cold side of the building's fabric

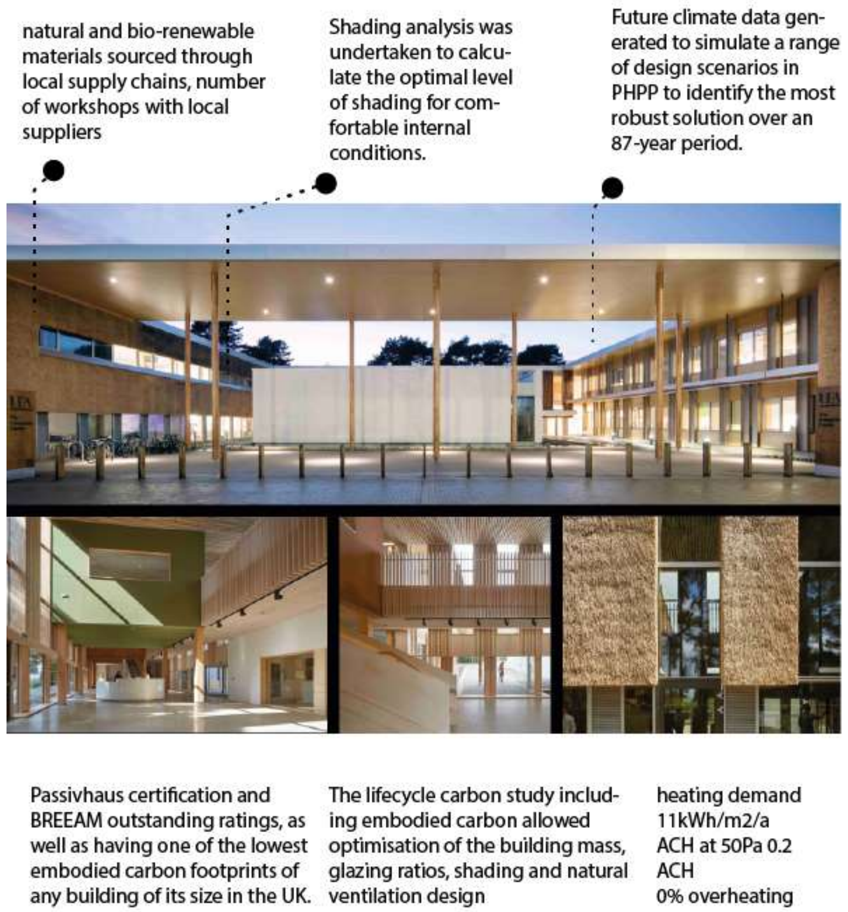
Based on Passivhaus rules of thumb document.

Recommendations implemented in my design:

- Increased thermal mass with using gabions and shingle roof for terraces
- Implementing airtightness strategy by having continuous insulation
- Using high quality windows with good u values and heat- absorbing glass with lower solar transmittance but maintaining daylight

<u>Passivhaus case study:</u>

The Enterprise Centre, Adapt Low Carbon Group at the University of East Anglia (UEA) in Norwich
Total Floor Area : 3425 m2 Gross External Area: 3797 m2 Form Factor: 2.92 Construction: Timber Frame Heat Source: University CHP (combined heat and power) via the local heat network, which is fuelled from burning non-toxic waste materials etc. 100-300 occupants



Recommendations implemented in my design:

- Modelling with future climate data to anticipate worser scenarios, e.g. higher temperatures
- Considering shading, especially for the glass pod structures, which is discussed further on.
- Timber frame structure and local flint/ masonry with low EE and EC as well as reuse potential.

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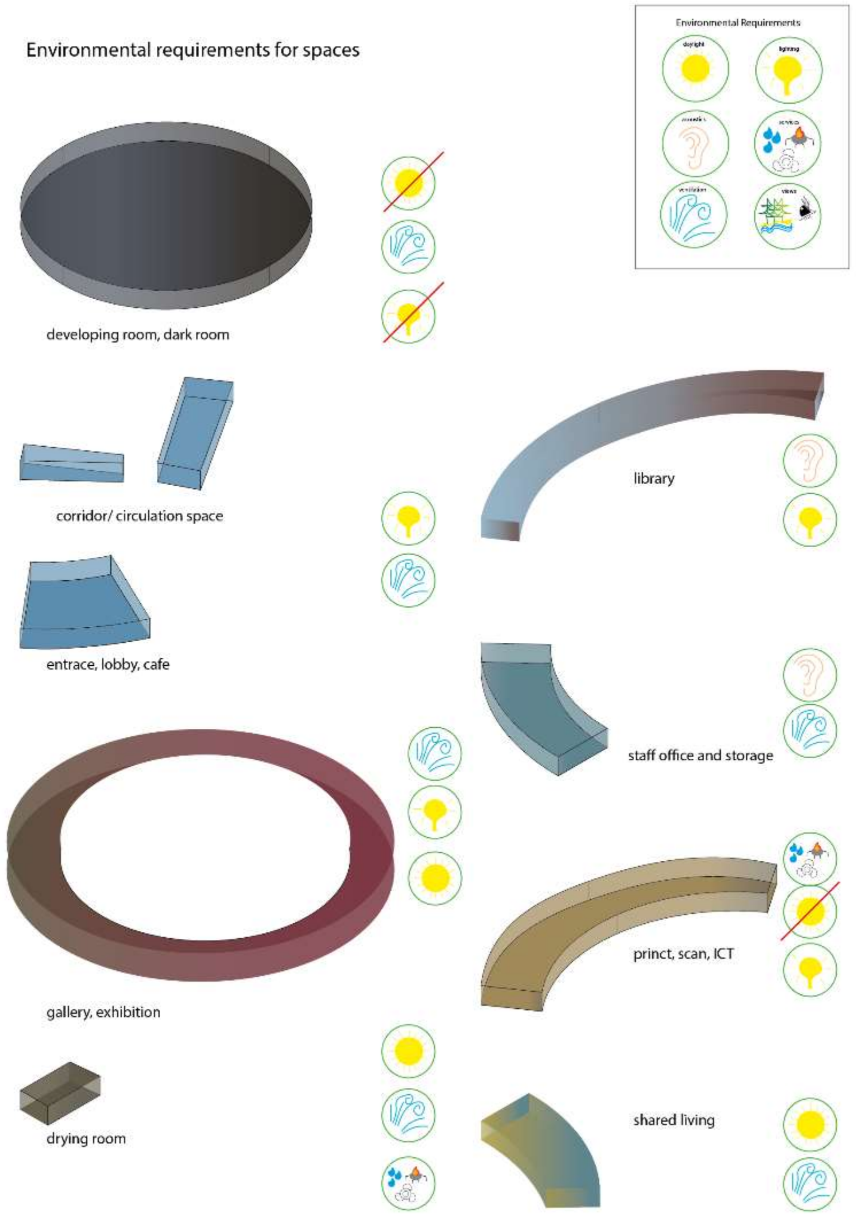
Room requirements

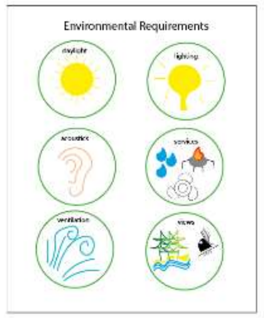
	Shared living	Kitchen	Exhibition	Private living	Dark room	Chemical storage	Scanner, IT, print	Dryer room	Office	Library
Natural light	Y	Y	Y	Y	N	N	N	Y	Y	Y
Ventilation	Y	Y	Y	Y	Y (extract)	Y (extract)	N	Y (humidify)	Y	Y
View to outside	Y	Y	Y	Y	N	N	N	N	Y	Y
Acoustic privacy	N	N	N	Y	N	N	N	N	Y	Y

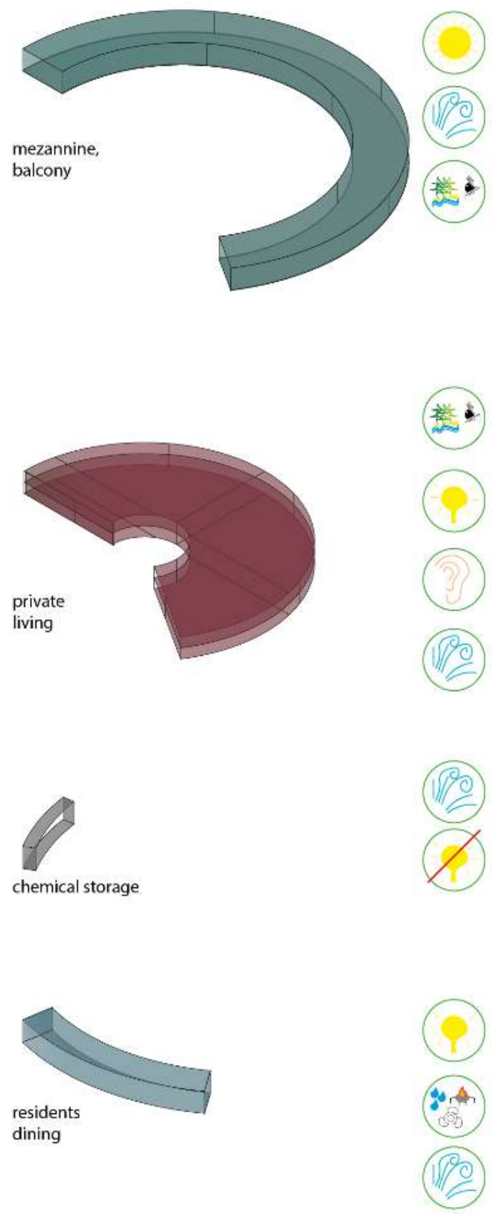
Iteration 1: Initial considerations for environmental requirements included considering light and ventilation, especially for the specialist spaces such as the dark room and gallery space.

<u>Updated requirements:</u>

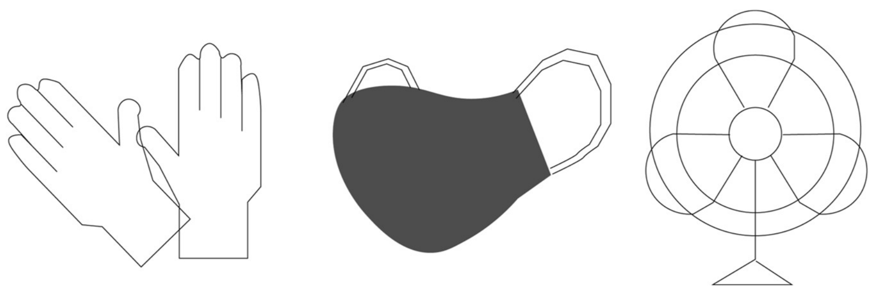


Environmental requirements for spaces

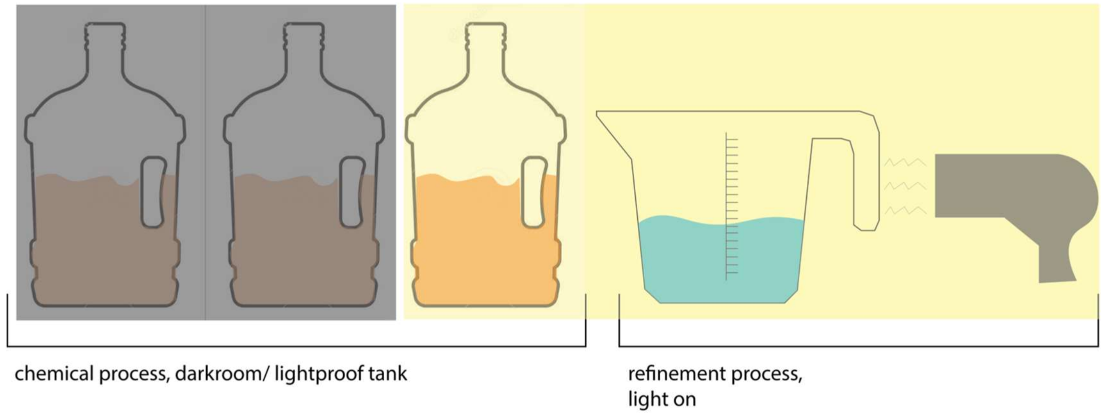




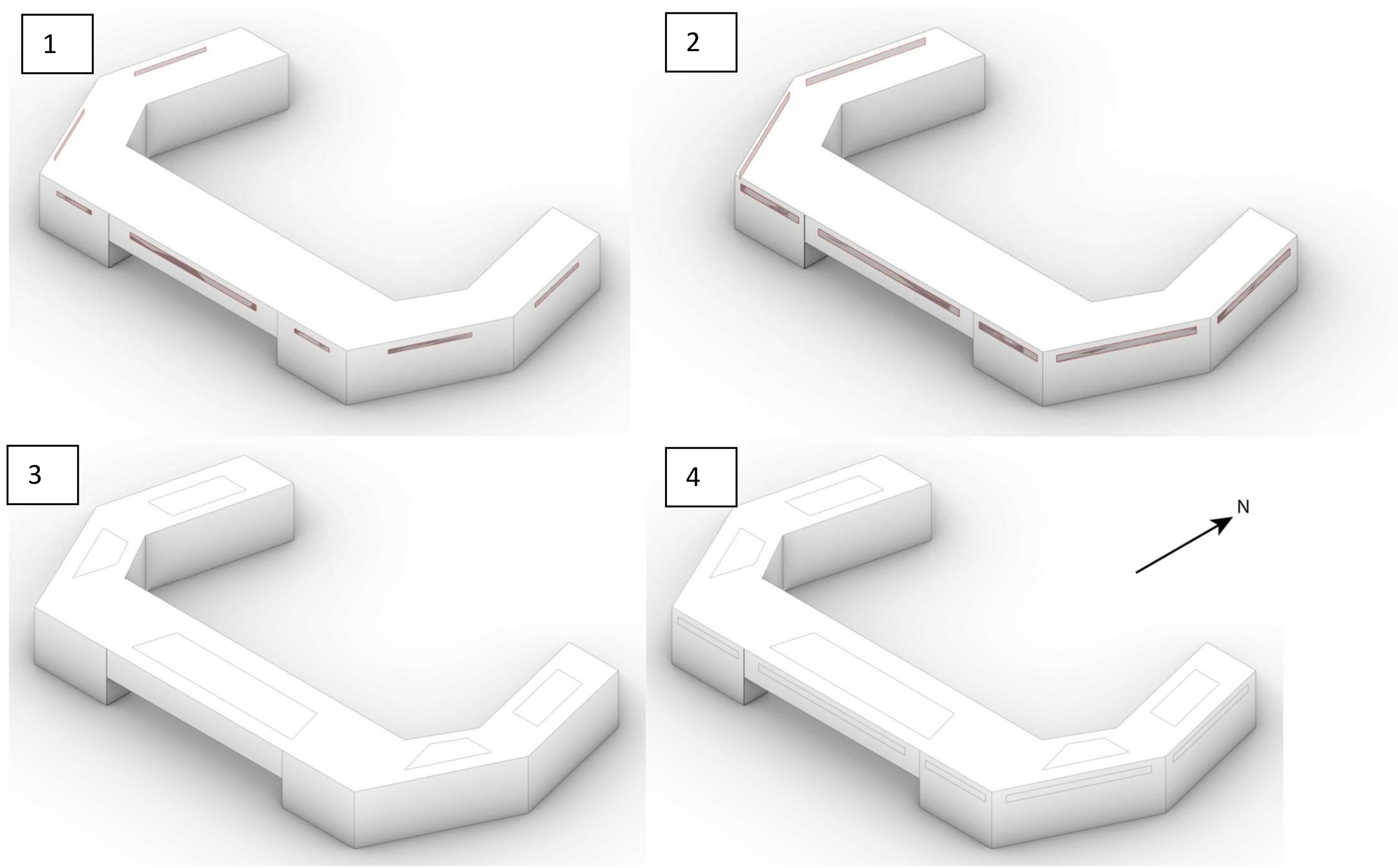
More specific requirements for dark room and photography developing:



Ventilation, dark room.



Thermal simulations for first iteration of gallery space



different glazing options for gallery space Further iterations: major reintroduction of light

1. Baseline - 12% of wall glazing on first floor in gallery space

Baseline performance summary: 1.2 % above comfort, 32% below comfort 66.4% comfort in non-heating season, occupied time annual heating load 56.5kWh/m^2. The highest heat losses are from conduction.

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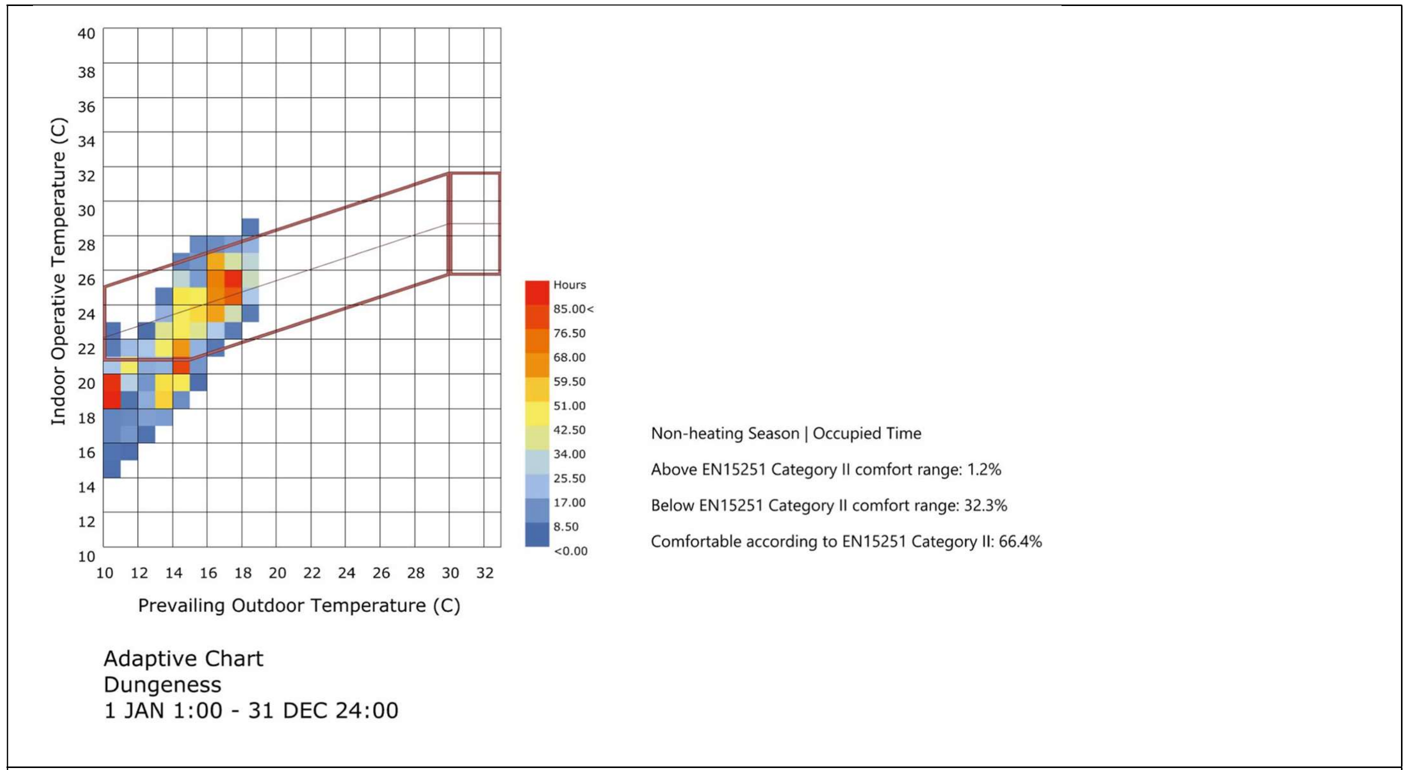
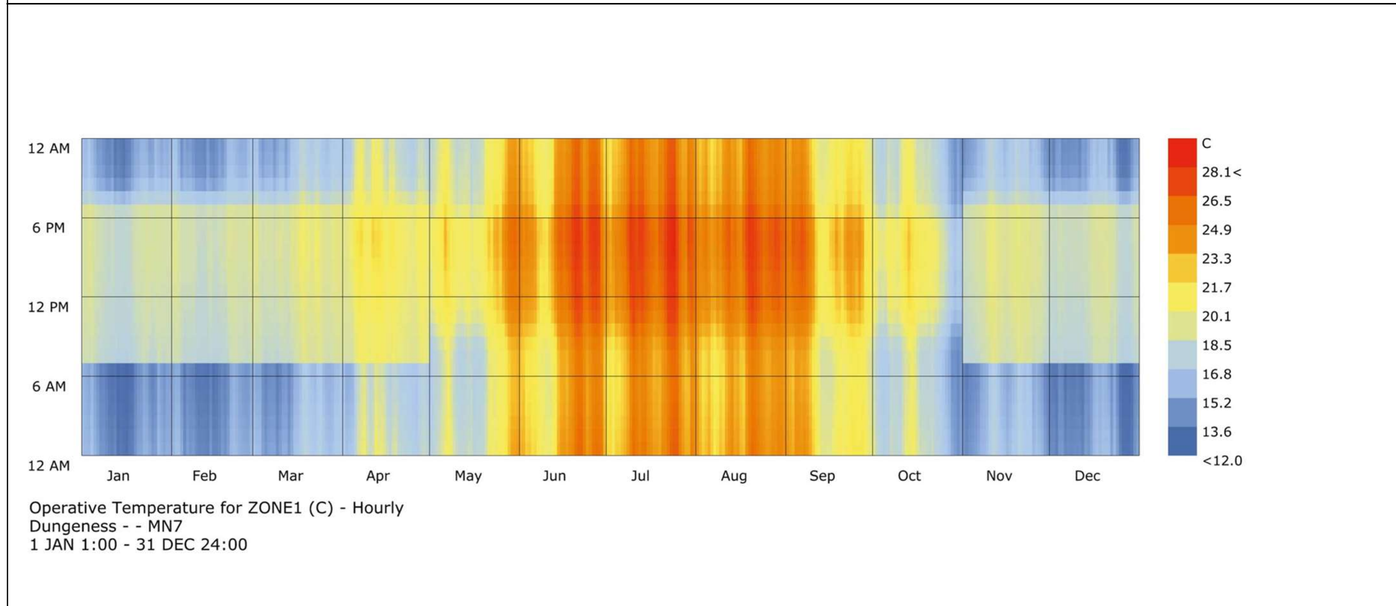
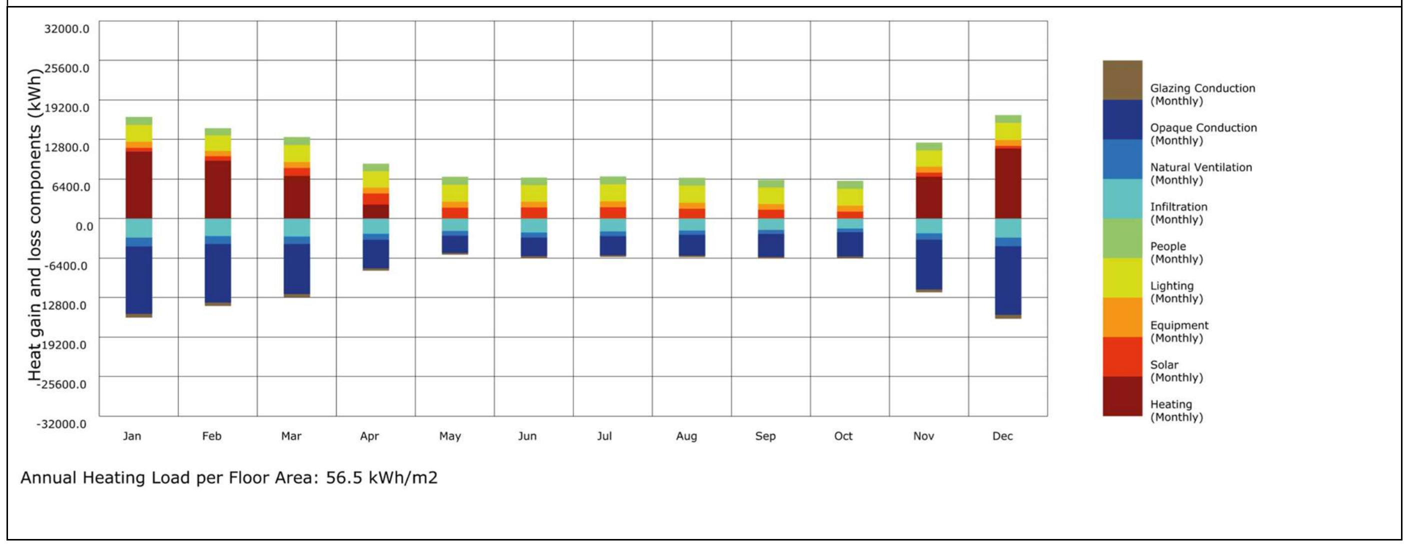
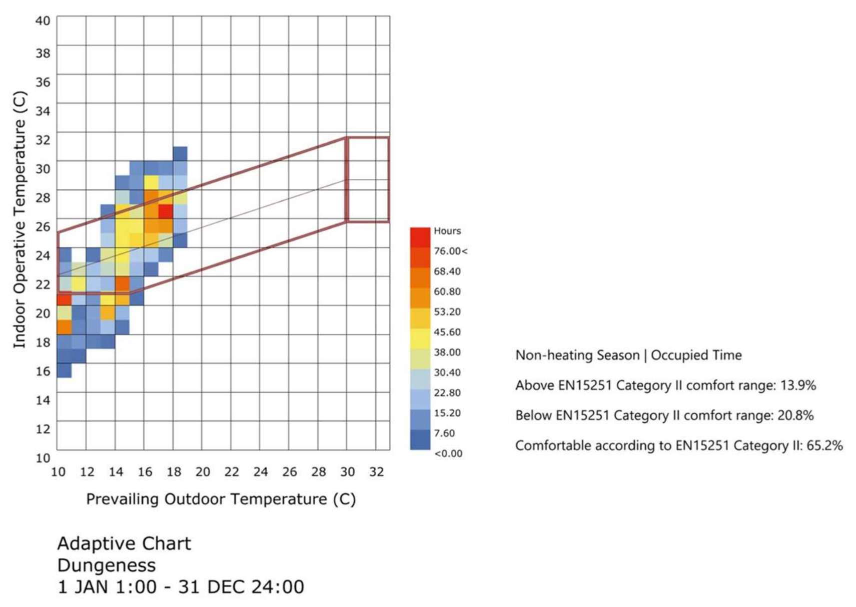


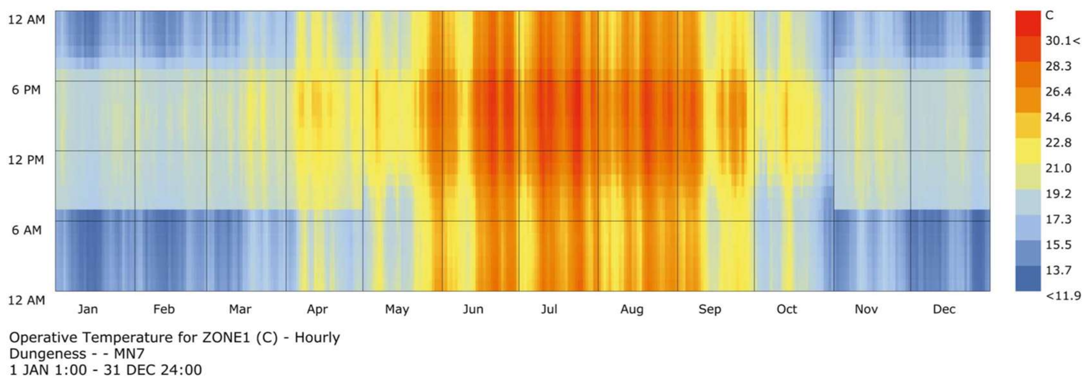


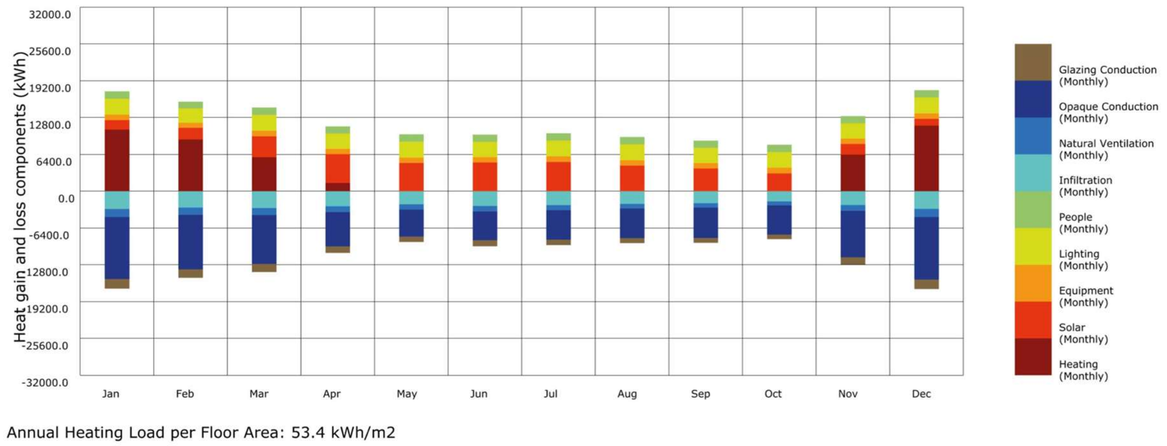


2. <u>20% of wall glazing on first floor in gallery space</u>

Higher glazing ratio summary: 14% above comfort, 21% below comfort: discomfort more towards being hotter than cooler 65.2% comfort in non-heating season, occupied time= 2% lower annual heating load 53.4kWh/m^2 = 5.5% lower







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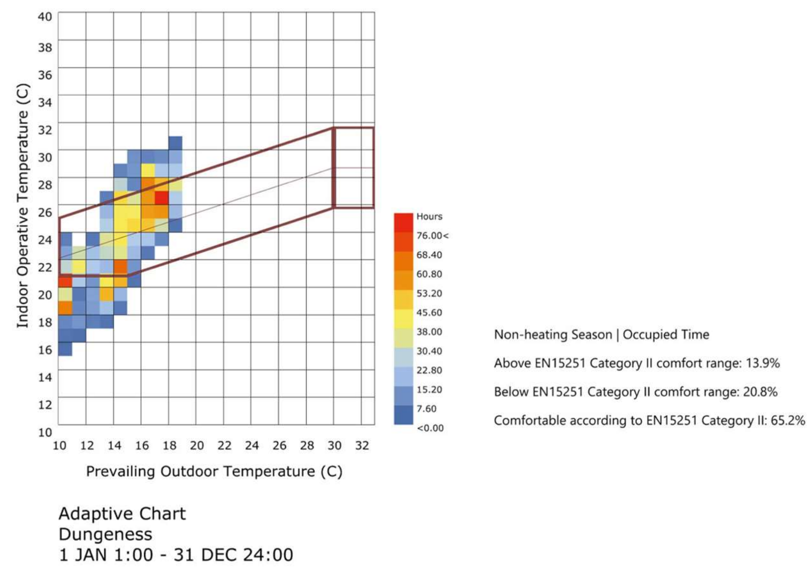
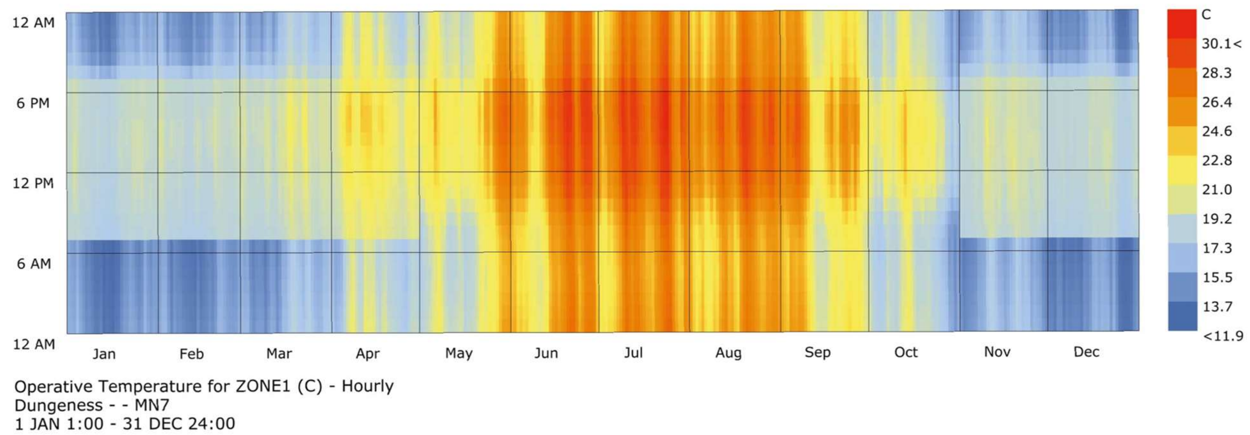
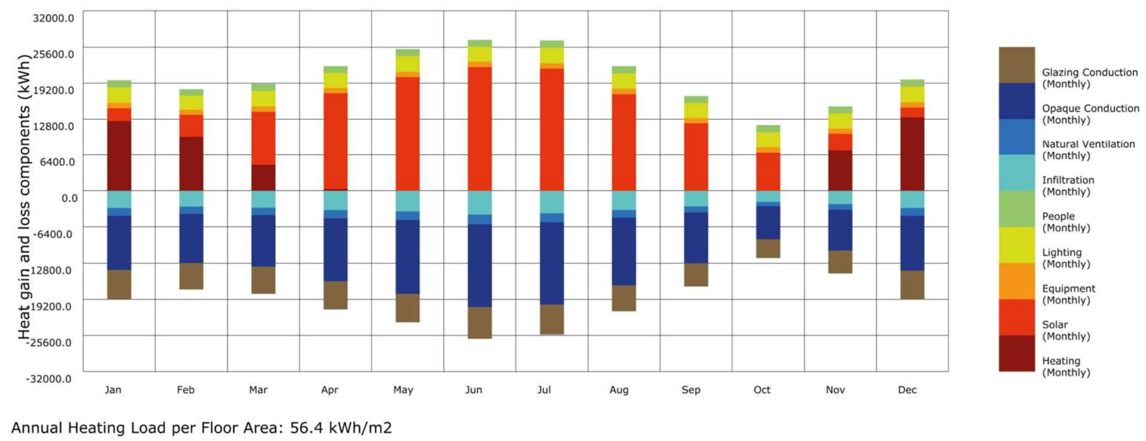
3. <u>Flat roof glazing 25% roof area</u>

Roof lights performance summary: 14 % above comfort, 21% below comfort 65.2% comfort in non-heating season, occupied time, 2% higher annual heating load 56.4kWh/m^2~ same. Adding glazing significantly increases solar gains and fabric losses.

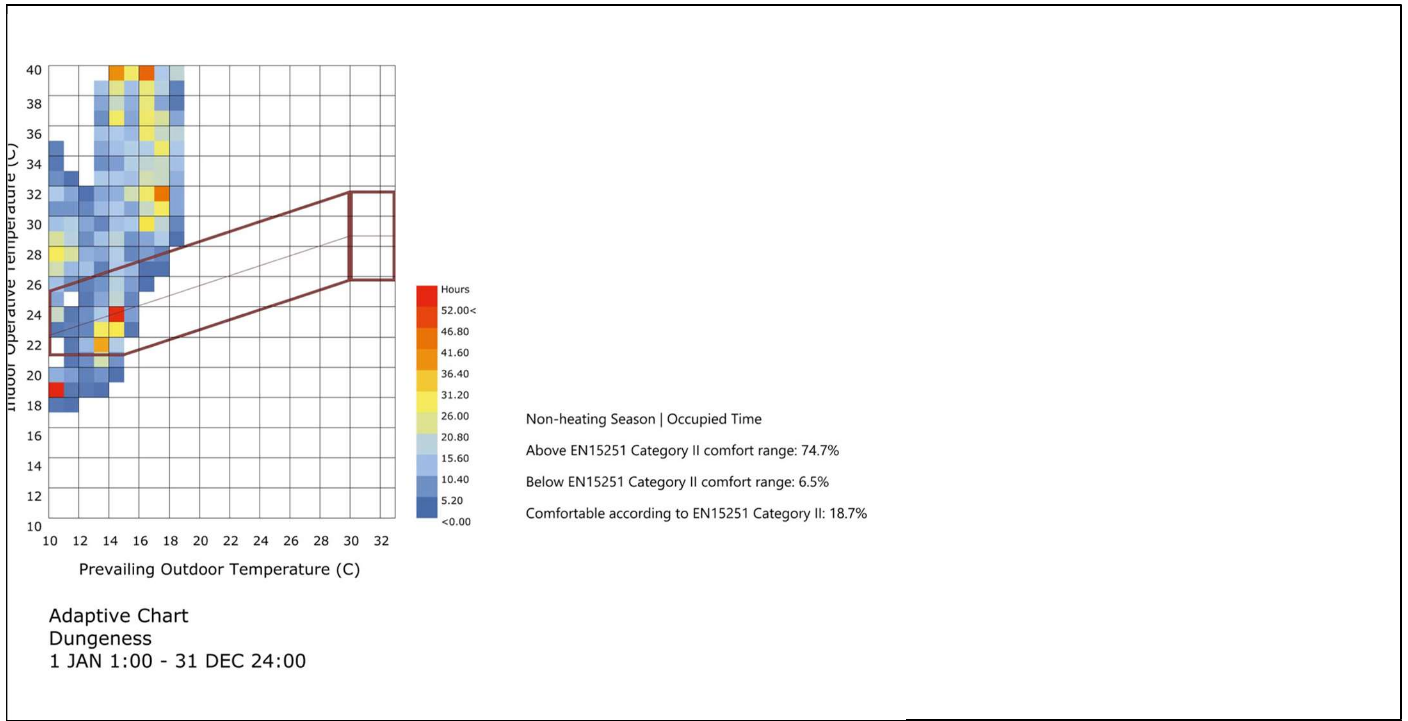


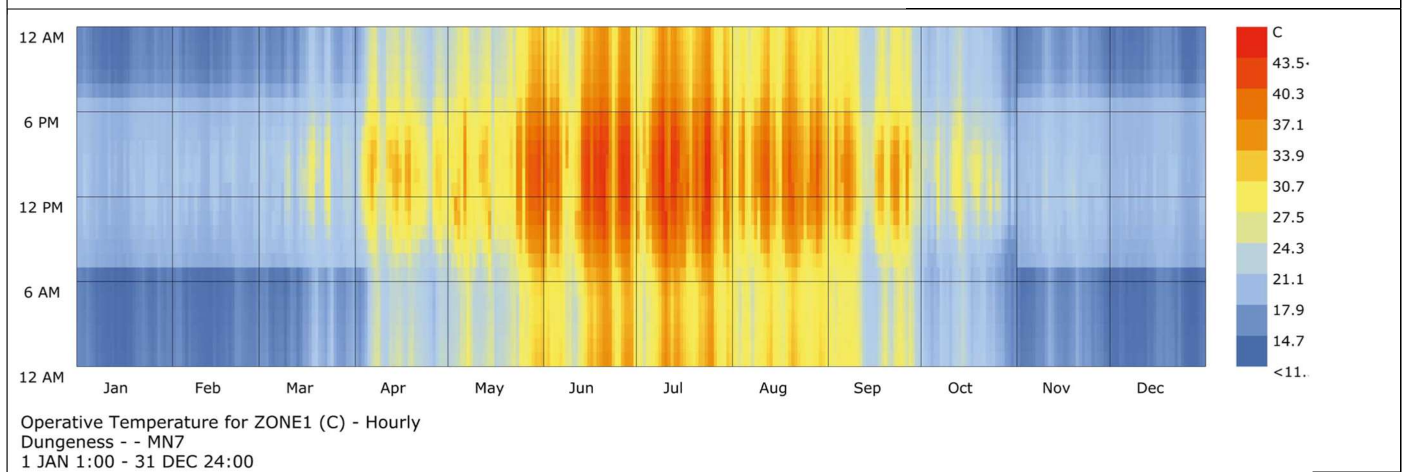


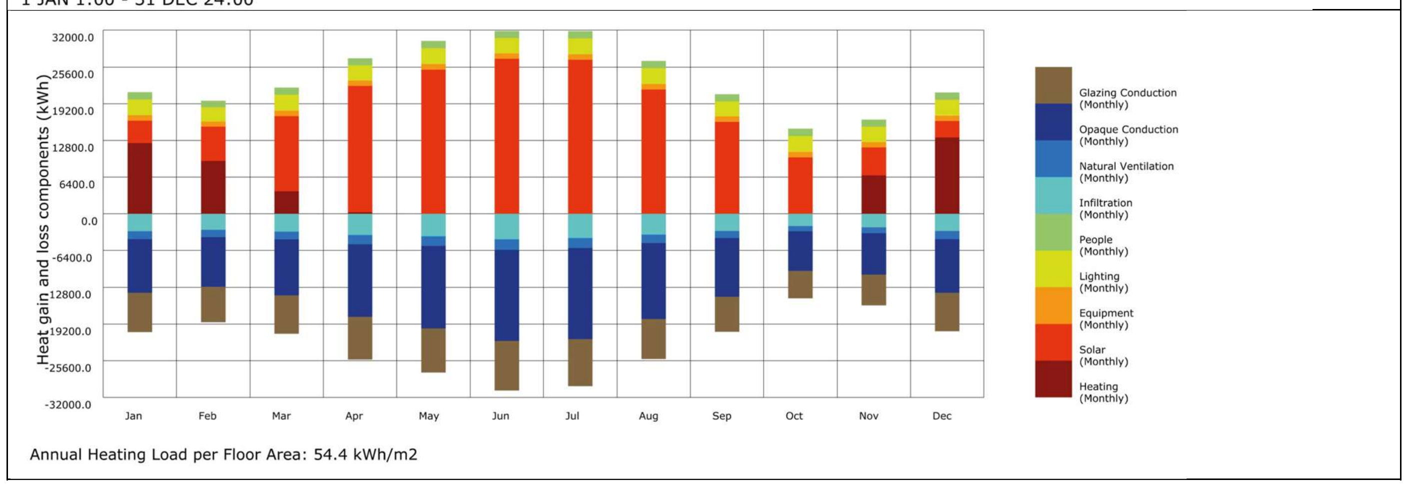


4. Flat roof glazing 25% roof area and wall glazing 25% wall area

Roof lights and wall glazing 75% above comfort, 7% below comfort: discomfort more towards being hotter than cooler 18.7% comfort in non-heating season, occupied time= 72% lower, lower annual heating load 54.4kWh/m^2 = 4% lower. Solar gains and fabric losses are again very high, and will be discussed further and optimised in line with Passivhaus guidance.







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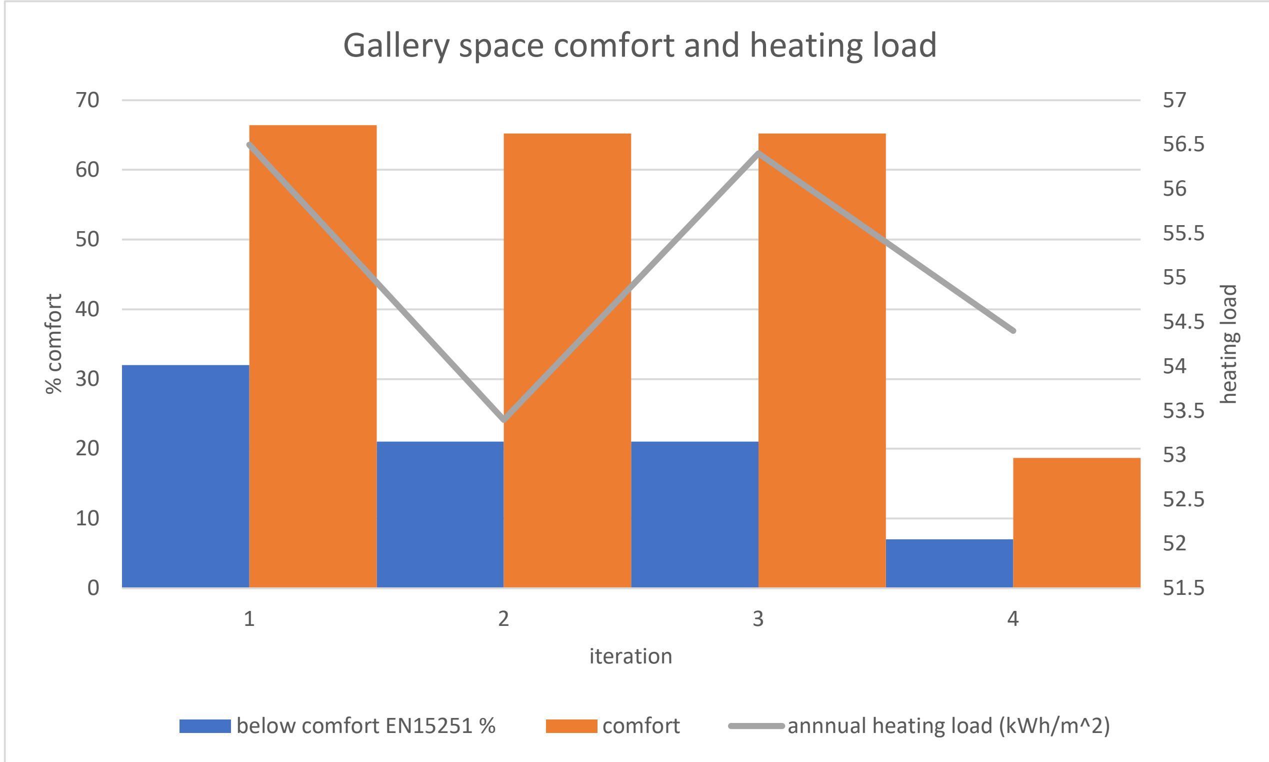


Conclusions: roof and window glazing compromises thermal performance and comfort. Having a high glazing ratio reduces thermal comfort due to high temperatures. However higher glazing may reduce heating demand.

Next iterations: explore variety of glazing orientations, shading options, and geometries to limit direct light and high heat gains, e.g. steep wall incline, roof reflectance.

Visual simulations for first iteration of gallery space

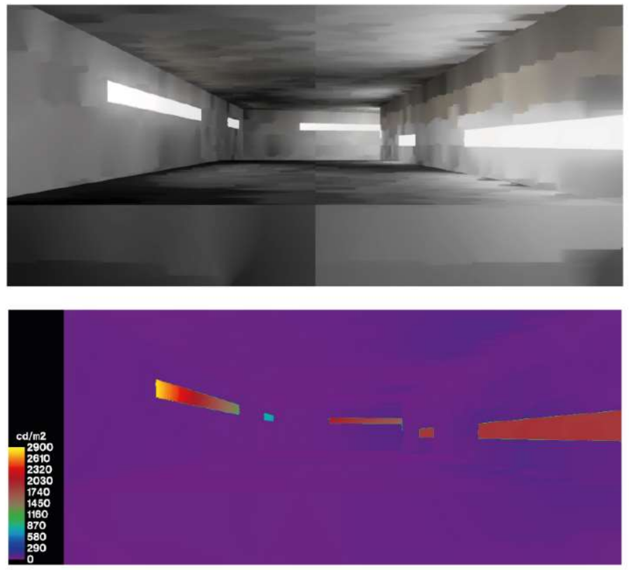
Climate Based Point in time image-based Model Comparing glazing options in Winter solstice at 3pm for worst case scenario with lowest sun angle Candelas/m^2 luminous power per unit solid angle emitted by light source in a particular direction.

DGP ranges Imperceptible <0.35 Perceptible 0.35<DGP<0.4 Disturbing 0.4<DGP<0.45 Intolerable >0.45

All values fall within imperceptible range, no glare problem

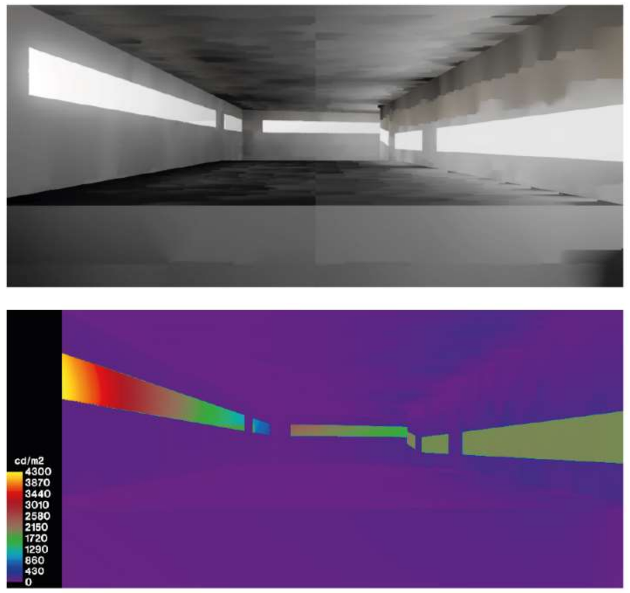
Conclusions: lowest DGP is achieved by Rooflights which give a more even lighting of the space and less direct light on a wall, high glazing ration good for well-lit space but needs to be diffuse. This is discussed later in the daylight strategies, for example having pitched rooflights and using strategies such as light shelves.

glazing 12% wall area of first level gallery space



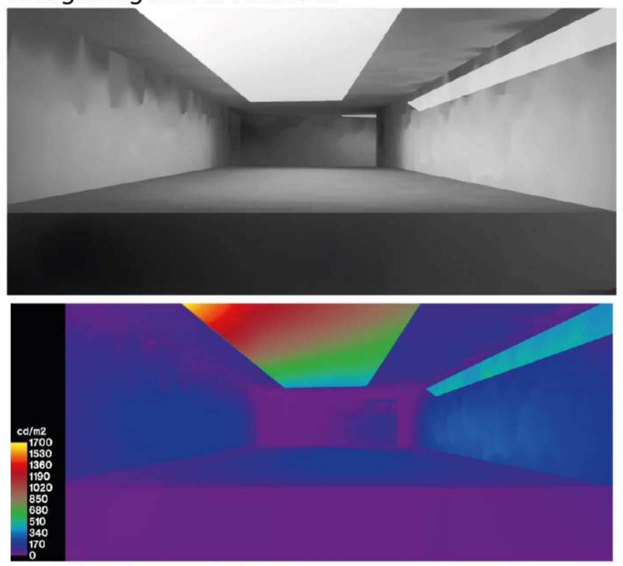
Daylight glare probability DGP = 0.0142

glazing 20% wall area of first level gallery space



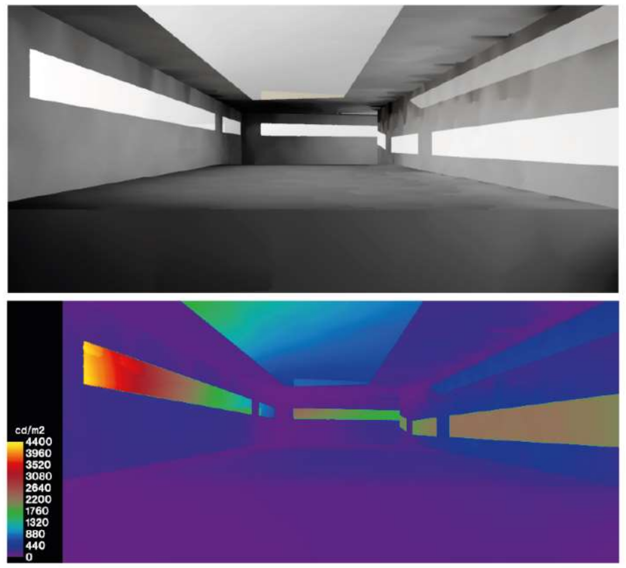
Daylight glare probability DGP = 0.0589

roof glazing 25% of roof area



Daylight glare probability DGP = 0.025

roof glazing 25% of roof area and wall glazing 25% of wall area



Daylight glare probability DGP = 0.155

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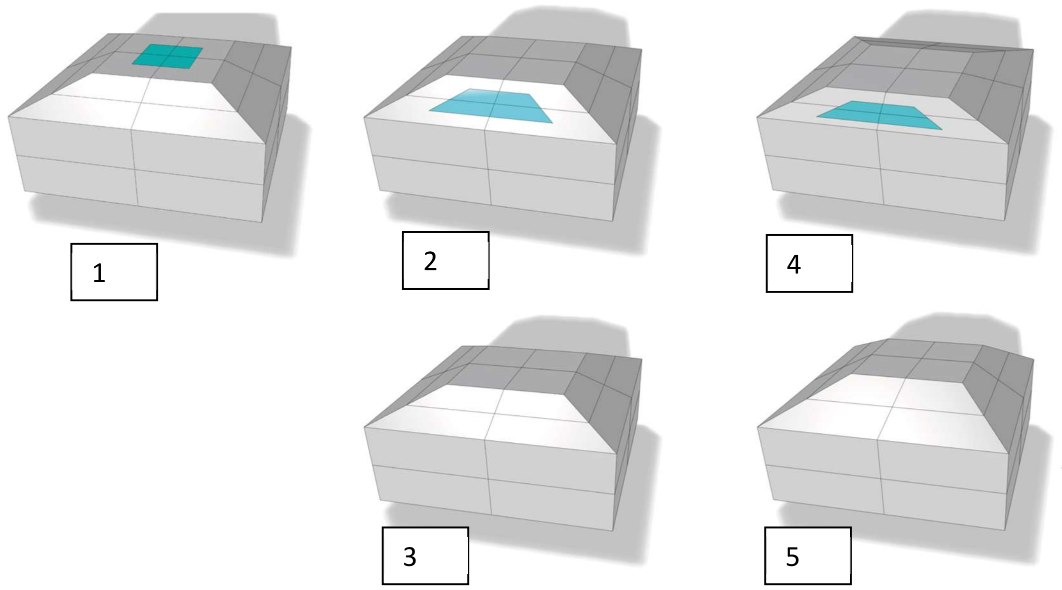
Roof Glazing Options- DF and Thermal Comfort comparison

Shoebox Model

Testing different glazing option orientations and roof angles-Adaptive comfort, operative temperatures and heating loads.

Testing:

1. flat rooflight
2. South glazing on a roof pitched at 47 degrees
3. North glazing on a roof pitched at 47 degrees
4. South glazing at a steeper angle at 65 degrees
5. North glazing at a steeper angle at 64 degrees

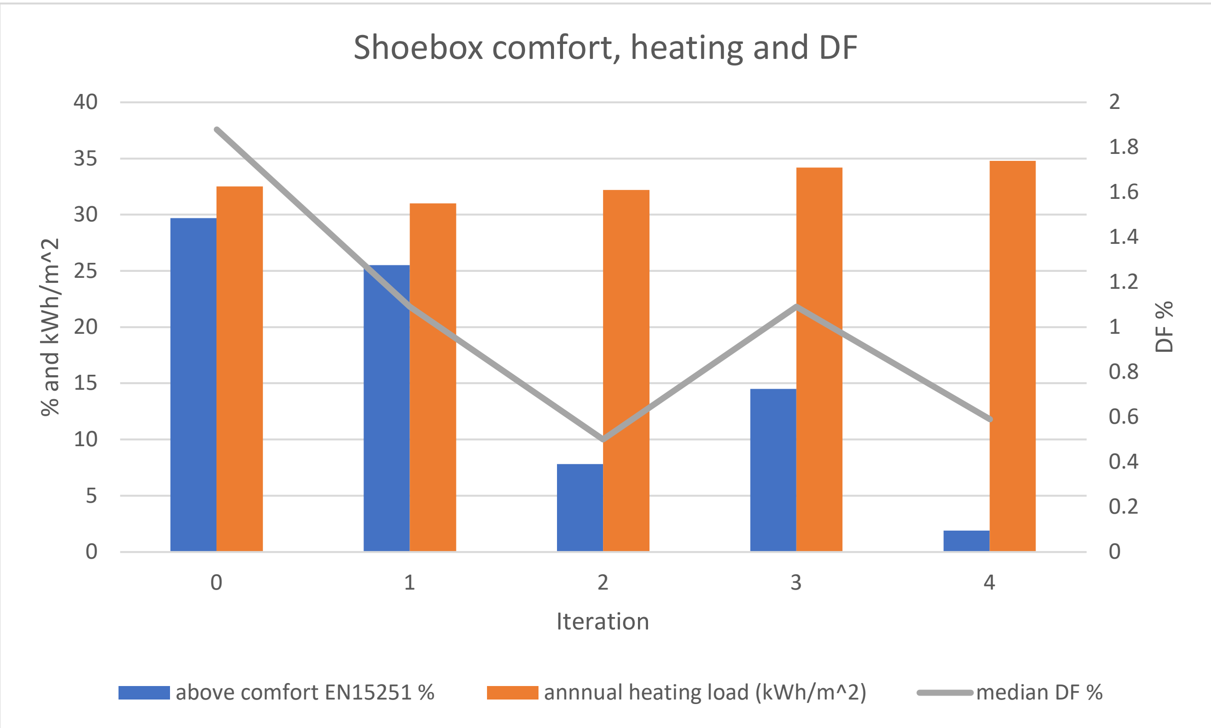


Inputs:

- Shoebox dimensions: 10m x 10m x 3.5m
- wall u value 0.70, Roof u value 0.65, Floor u value 0.66, Window u value 3.1
- Residential occupancy, hotel: 23.2people/m2
- Tight building:0.0001 m3/m2 facade infiltration at 4Pa
- Equipment 3.5 W/m2, Lighting 13.2 W/m2
- Free-running period between May and October
- Natural ventilation In non-heating season:

Iteration	Description	Free-running period			Heating Season	Minimum DF (%)	Median DF (%)
		Above comfort (%)	Comfort (%)	Below Comfort (%)	Annual Heating Demand (kWh/m^2)	BSEN Targe 0.8	BSEN Target 2.3
0	Flat Rooflight	29.7	59.1	11.1	32.5	0.7	1.88
1	Pitched Rooflight (S)	25.5	64.8	9.7	31.0	0.21	1.09
2	Steeper Rooflight (S)	7.8	77.9	14.3	32.2	0.11	0.5
3	Pitched Rooflight (N)	14.5	69.3	16.2	34.2	0.21	1.09
4	Steeper Rooflight (N)	1.9	75.7	22.3	34.8	0.11	0.59

- Best Comfort based on adaptive model: Steeper Rooflight, South
- Best Heating Load: Pitched rooflight, South
- Best Daylight Factor: Flat Skylight



This graph shows how it's difficult to achieve comfort across the different criteria, therefore it's necessary to prioritise between them and define a leading variable to focus on for each space. For example, for a part of the gallery space the Skylight option is most appropriate at DF is prioritised, whereas for the upstairs office a steeply pitched skylight is more appropriate to prioritise occupant comfort.

The results also show that in general, the glazing ratio is too low as the DF is very low and doesn't meet the BSEN targets, therefore much larger glazing and application of daylight solutions is needed.

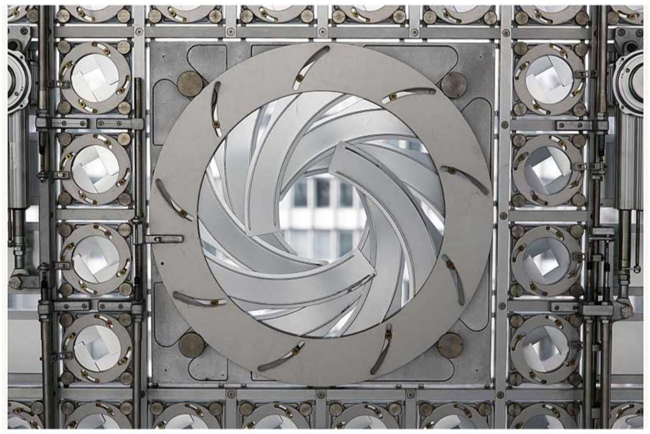
Shading solutions

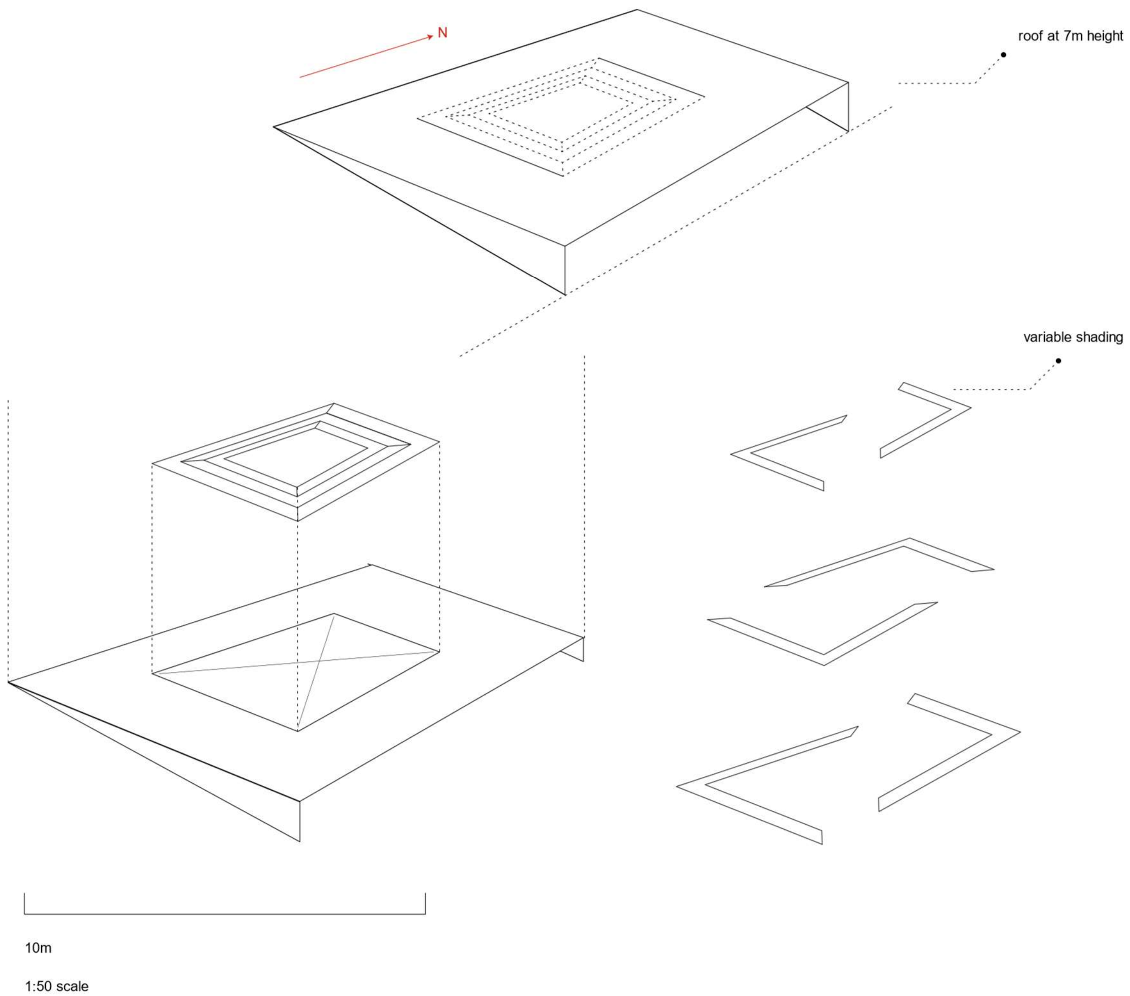
Case study:

Dynamic facade of Institute of Arab World, Paris. Enrique Jan + Jean Nouvel + Architecture-Studio, 1987

Visible behind the glass wall, a metallic screen unfolds with moving geometric motifs. The motifs are photo-sensitive motor-controlled apertures, or shutters, which automatically open and close to control the amount of light and heat entering the building from the sun. The mechanism creates interior spaces with filtered light — an effect often used in Islamic architecture with its climate-oriented strategies

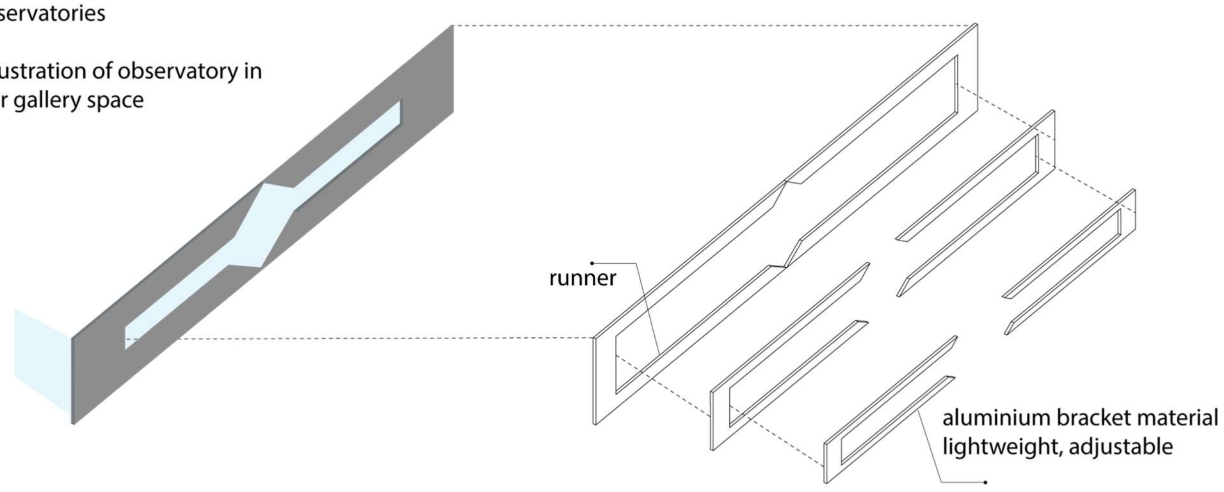
This dynamic system inspired me to create a version for the roof lights or glass pods, to regulate light and create interesting views for the photographers.

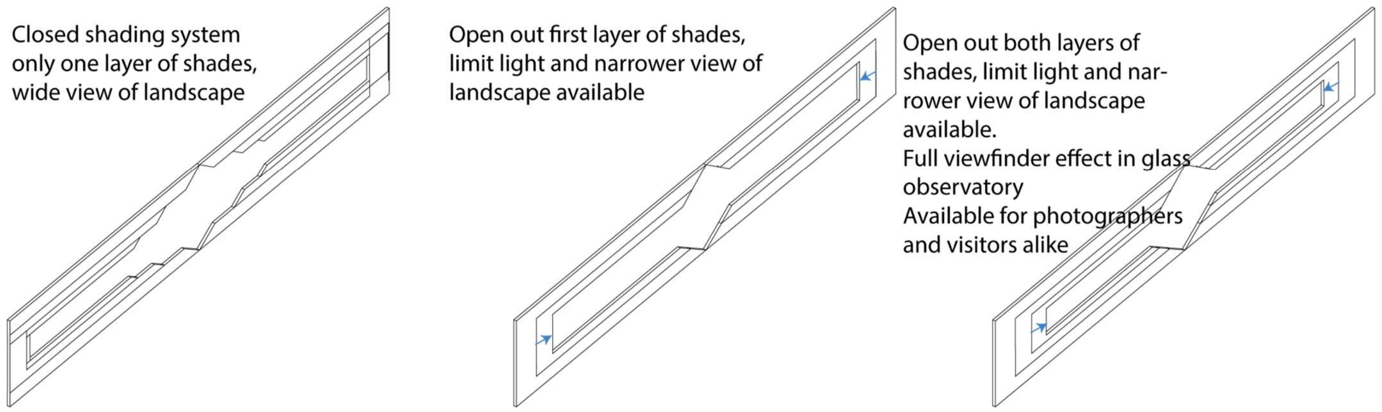




Viewfinder Shading system for glass observatories

Isometric illustration of observatory in ground floor gallery space



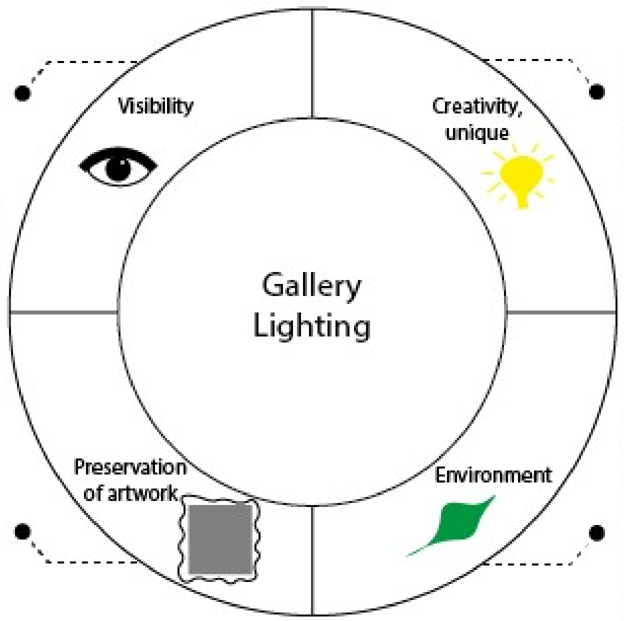


Requirements of gallery space

Based on recommendations in Lighting for museums and galleries brochure

https://www.sylvania-lighting.com/documents/documents/Museums%20and%20Galleries%20-%20Brochure%20-%20English.PDF

Lighting can be used to alter the mood of the exhibition space.
Visibility is dependant on colour rendering, colour temperature, placement of artificial lights and placement of objects in daylight

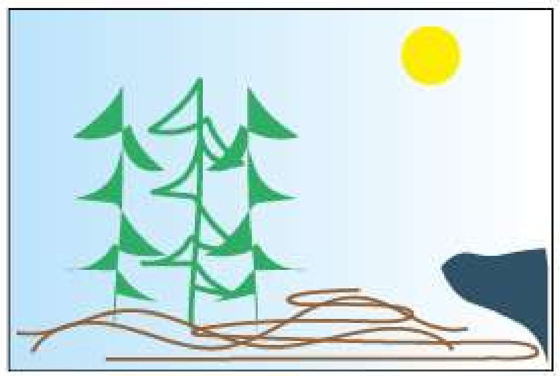


Lighting plays a vital role in guiding visitors through their museum or gallery experience and communicating drama or contemplation within the exhibition space

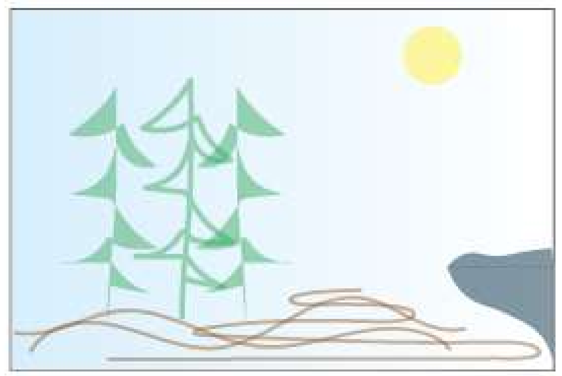
It's important to safeguard the longevity of the artwork and protect sensitive photos from IR and UV rays from direct light, as well as heat damage

Maximising daylight use can cut energy demands and also be a part of the artistic journey in the gallery space.
It's also important to choose efficient and low-energy solutions when using artifical lighting

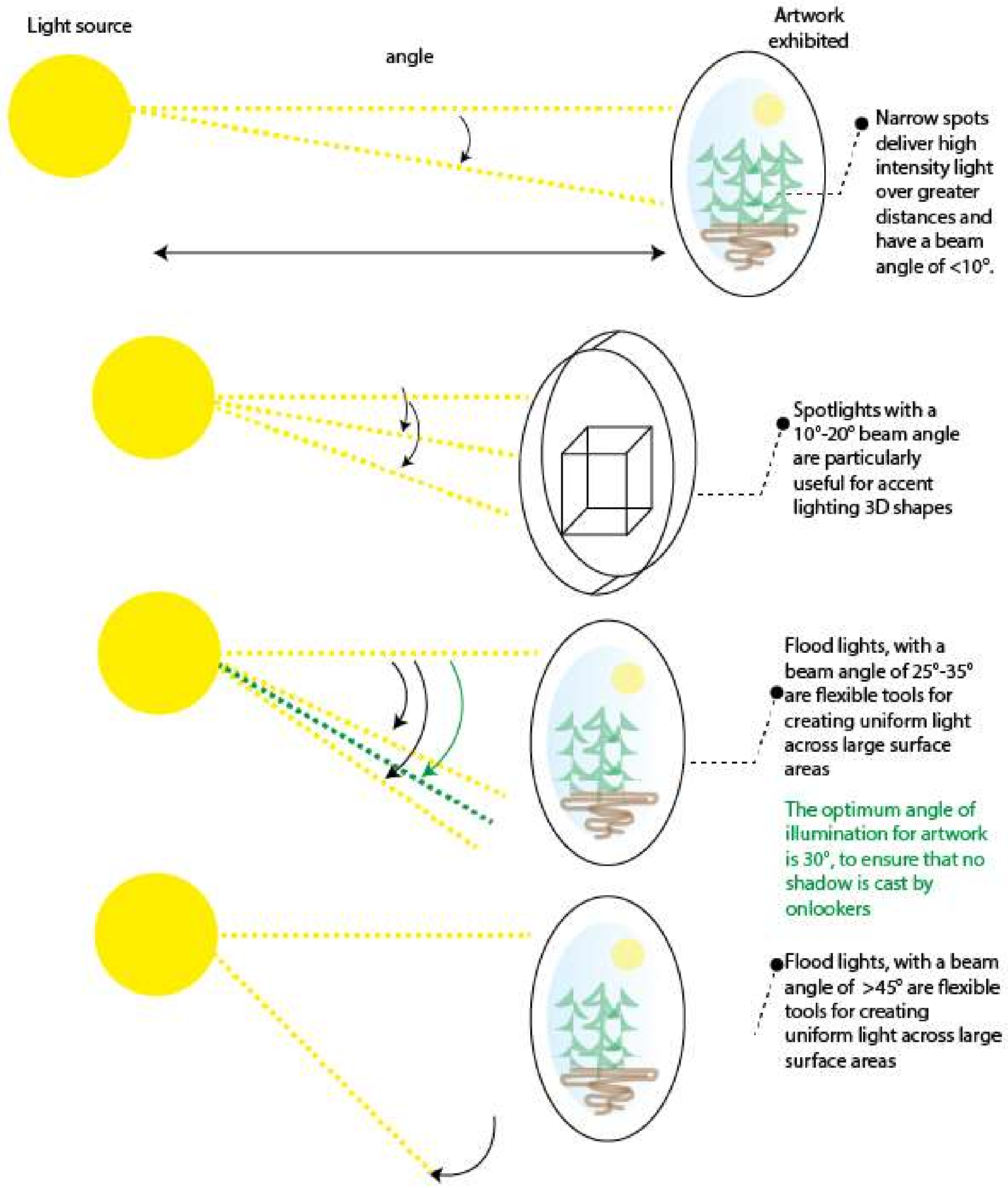
Traditionally the contrast ratio usually suggested for museums is 6 to 1 between the brightest and the dimmest objects in the field of vision and 2 to 1 for galleries.



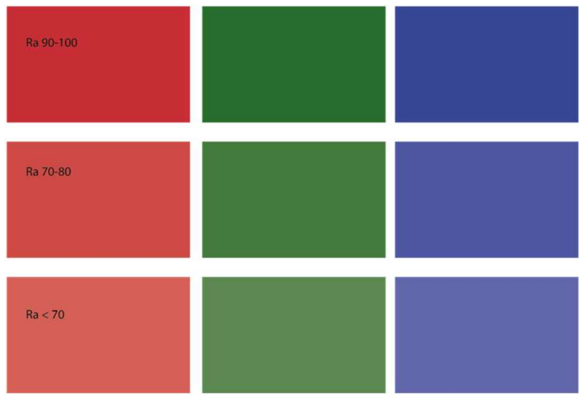
High levels of contrast direct the visitor to key focal points within the space and create a more theatre-like' experience



Low levels of contrast are ideal for creating a bright and airy space to draw in the visitor and allow them to explore the area as a whole

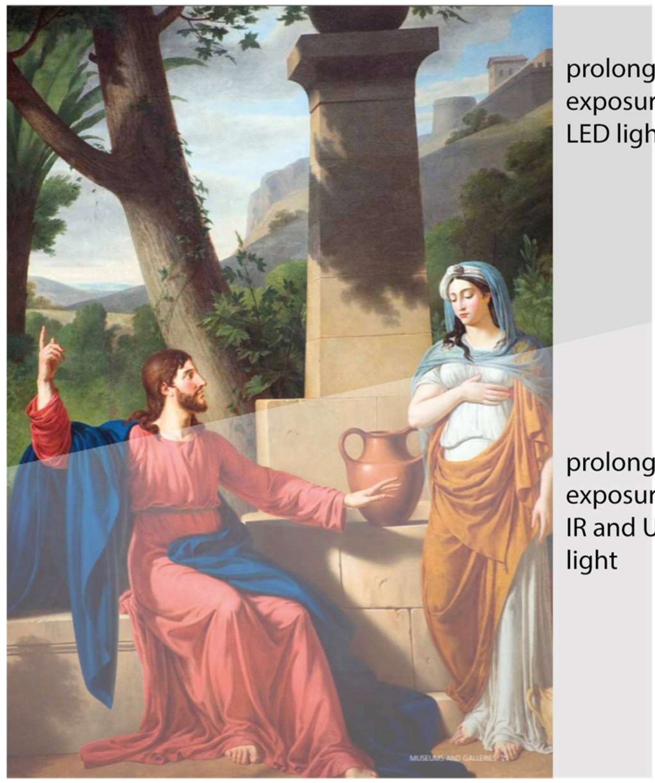


To achieve uniform wall washing, luminaires must be correctly positioned to minimise the risk of visitors casting a shadow and also to avoid reflective glare.



The Colour Rendering Index (Ra) gives a general indication of the rendering ability of a light source. A CRI of 100 is 'best or true', whilst those over 80 are considered good. LEDs traditionally create white light by combining blue light with a yellow phosphor, making them better at lighting blues than reds in the colour spectrum. The end result can be washed out reds and skin-tones. To avoid this, LEDs with a CRI of >90 are best for galleries and museums, to ensure vibrant reds. In terms of quality of light, daylight is unique; its colour

rendering is supreme; however the potential damage direct sunlight can cause in terms of UV radiation and heat has to be taken into account.



Daylight in galleries should be controlled and diffused, to avoid direct contact with exhibits. Light is a common cause of damage to artwork. Paper media are especially sensitive to light. Traditional lamps, even with protective filters, can damage exhibits in museums very quickly. LED technology however, does not create IR and UV light and is therefore ideal for sensitive environments such as galleries. The recommended light level is lux 100.

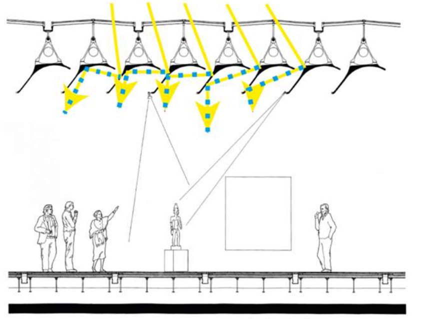
The colour temperature used to light an exhibit will not only affect the colour appearance of the object or space, but the mood communicated to the visitor. Colour adjustable LEDs increase the versatility of mood creation- from midday light levels (3000K) to warmer, softer tones of evening light (1600K), whilst still maintaining light quality and beam control. Daylight has best colour rendering qualities.

Therefore, this research has lead to capitalising on the use of daylight, and LED when needed, as well as using UV coating on glazing to protect the exhibits.

Light in Galleries case studies

Requirements for Gallery Space: - Daylight for good colour rendering - Avoid direct sun beam on artwork (around 1.4m height on walls) - UV protection to avoid fading of colours and damage to exhibits.

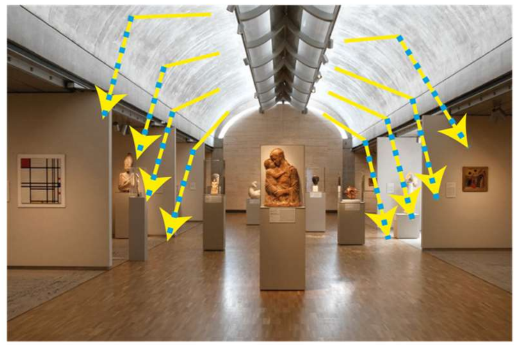
Menil Collection
Houston, Texas
Renzo Piano



Solution:
Additional reflective geometry to achieve diffuse light
No direct light to protect exhibits and for an even lighting inside

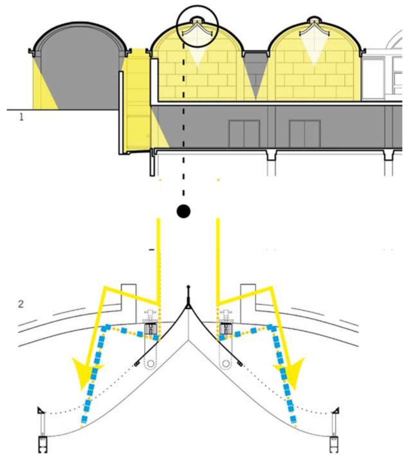
Light beam Diffuse Light

Kimbel Art Museum
Fort Worth, Texas
Louis Khan



Light beam Diffuse Light

Solution:
Domed Roof and geometry to achieve diffuse light
No direct light to protect exhibits and for an even lighting inside



Conclusions: Application for my gallery space: Consider designing roof geometry to reflect light and achieve diffuse daylit interior spaces. Also focus on orientation of openings/ low sun (case studies in Texas have more vertical sun path than in the UK.)

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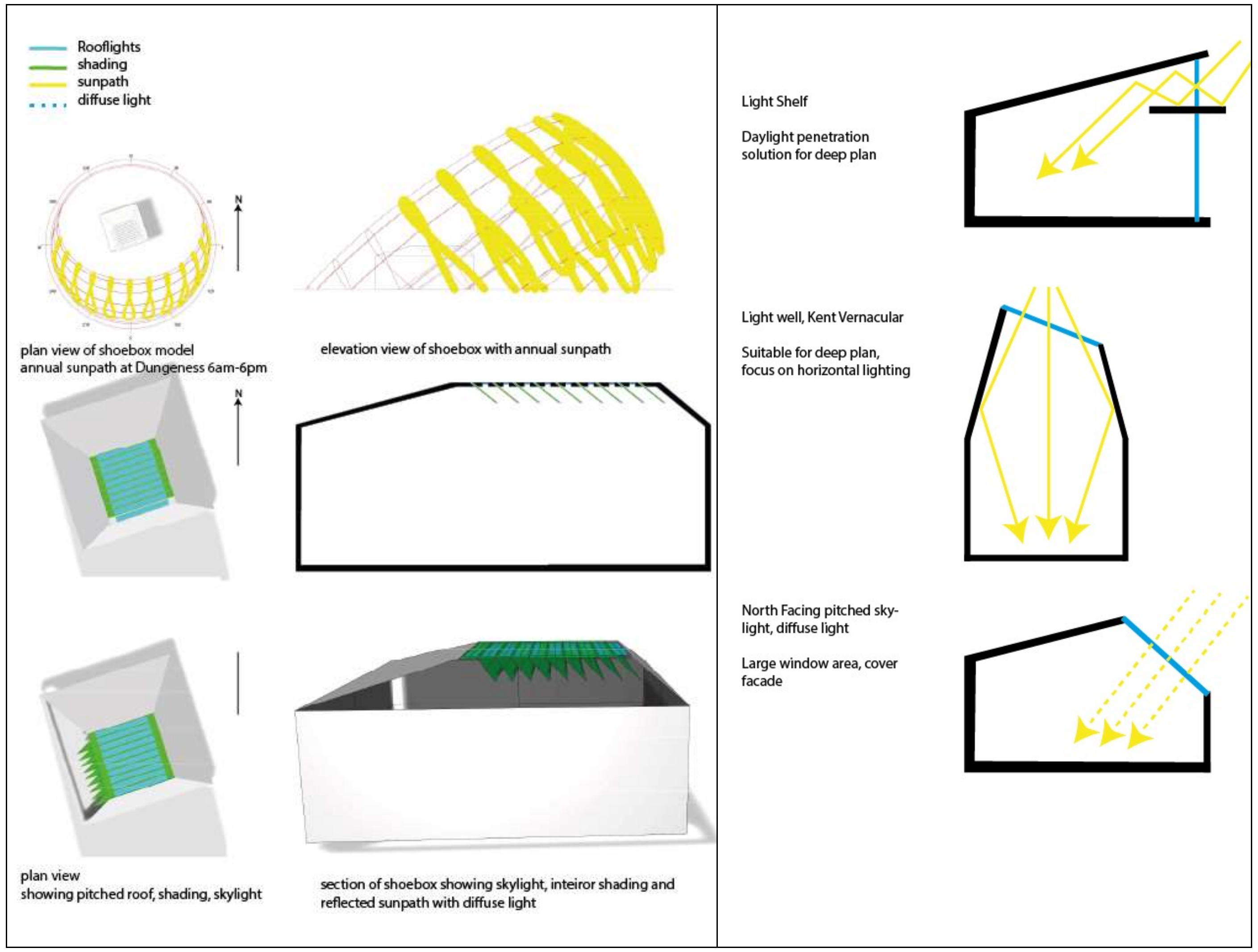
Solutions based on case studies

Shoebox Model input parameters:

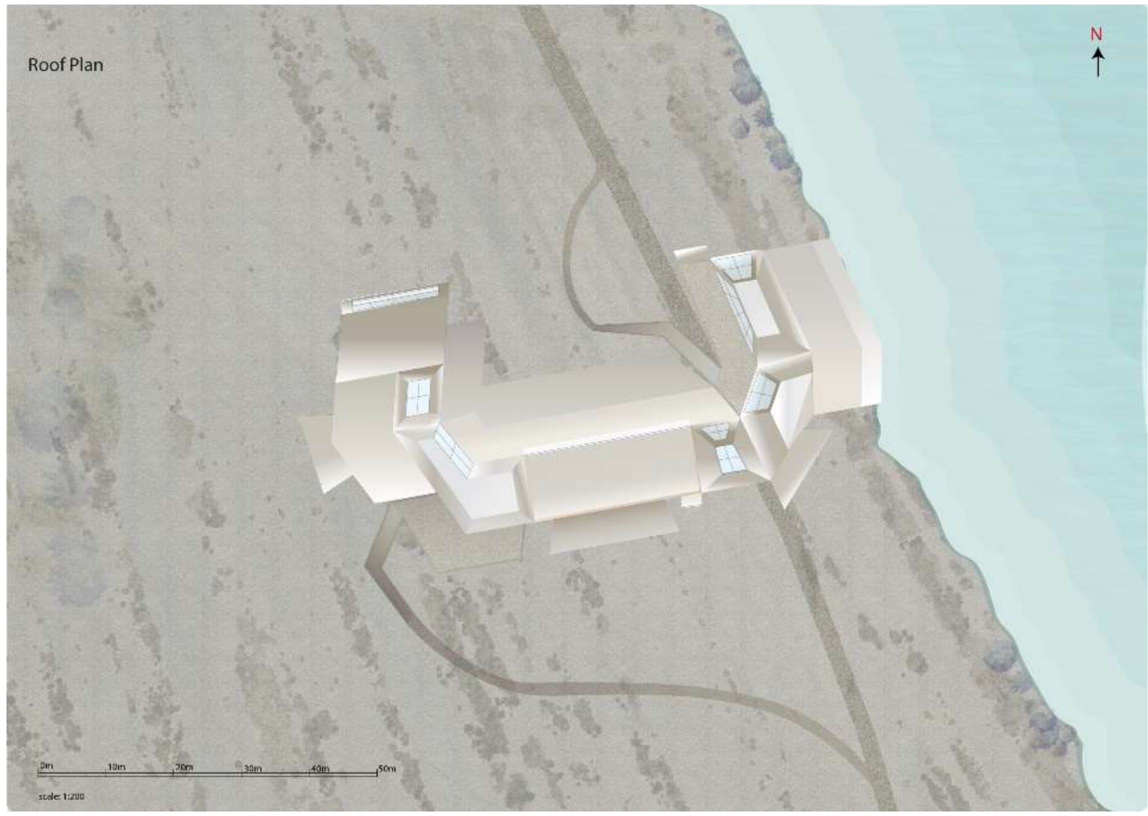
- 10m x 10m x 3.5m height
- Same orientation as gallery space, east façade parallel to quarry water's edge
- Pitched roof with rooflights and shading

Used alongside previously discussed solutions to achieve high daylight and still maintain good thermal performance.



Roof

Reintegrating shingle on roof terraces to link with landscape and have cohesive visual link. This also provides additional thermal mass and is part of the passive design strategy.

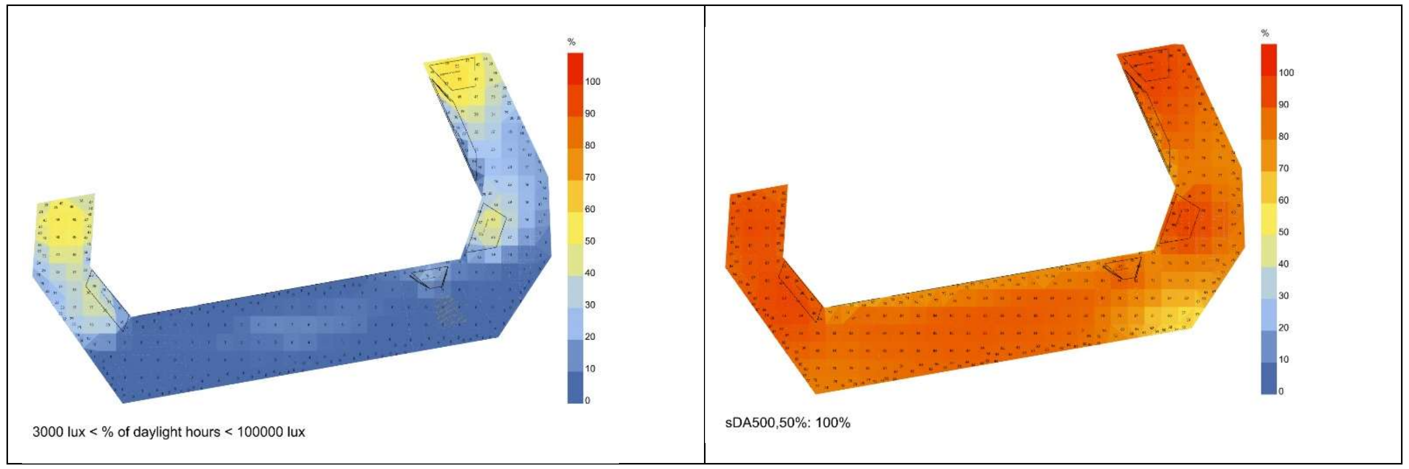


Final iteration gallery simulation

Input parameters:

- Wall and ceiling reflectivity 0.8 for white paint
- Floor reflectance 0.35 for timber finish
- Glass and skylight transmittance 0.6
- Light shelf reflectance 0.9
- Ground plane reflectance 0.3 for shingle

Average UDI-x (3000-10000lx)= 12.7 % of daylight hours. This is a proxy for glare and visual discomfort, therefore needs to be reduced.



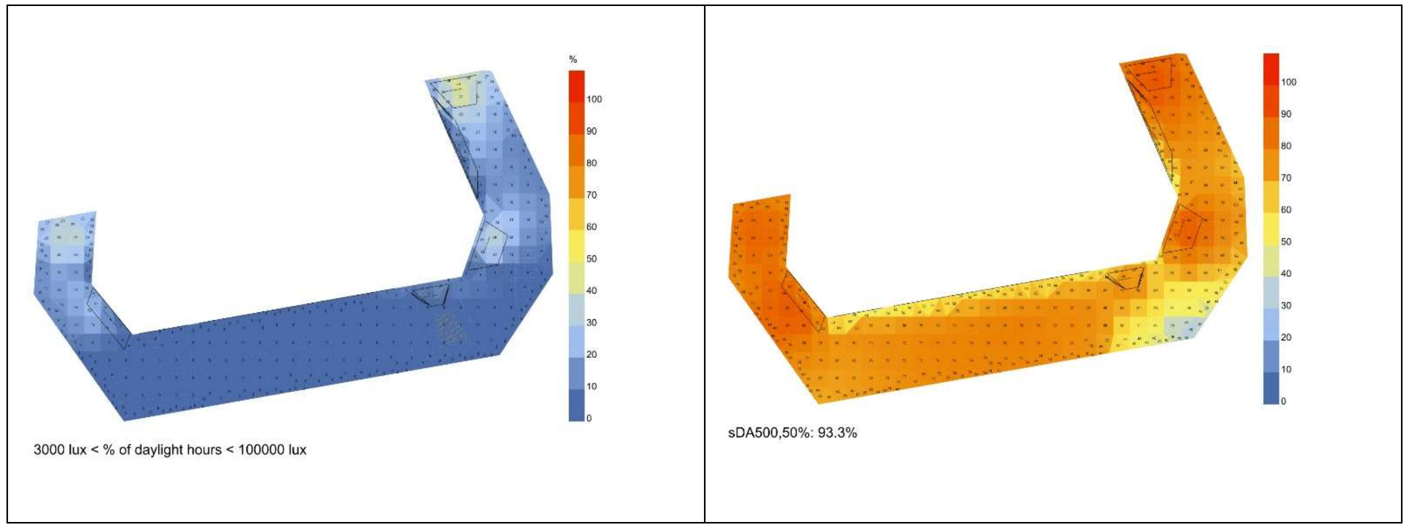
<u>Results:</u>

Some areas with too much daylight, especially with the large roof windows

<u>Updates:</u>

Change glass to heat absorbing glass with solar transmittance 0.4 based on Shimadzu catalogue.

Average UDI for range 5.8, this is reduced and much better.



sDA 500, 50% 93% is well above recommendation of 50% of area.

This model shows very good internal visual environment of the space and a high quality user experience with very good daylight provision. It is also quite evenly distributed in the space.

Final iteration energy simulation

Single zone thermal simulation on private living space.

Input parameters: (material properties for timber, insulation and glazing from IDF editor material catalogue)

- Insulated Timber wall and roof.
  Fibreboard 20cm thickness
  0.07 W/mK conductivity
  400 density kg/m^3
  1300 J/kgK specific heat
- Double glazed low solar transmittance windows
  0.5 solar heat gain coefficient
  0.6 visual transmittance
- Polystyrene insulation
  0.035 W/mK conductivity
  28 density kg/m^3
  1210 J/kgK specific heat
- Roof timber
  1.14 W/mK conductivity
  900 density kg/m^3
  1920 J/kgK specific heat
- ➢ Wall u value 0.243 W/m^2K
- ➢ Roof u value 0.167 W/m^2K
- ➢ Floor u value 0.184 W/m^2K
- ➢ Window u value 0.9 W/m^2K

Occupancy 23.2 m^2 per person based on hotel occupancy.

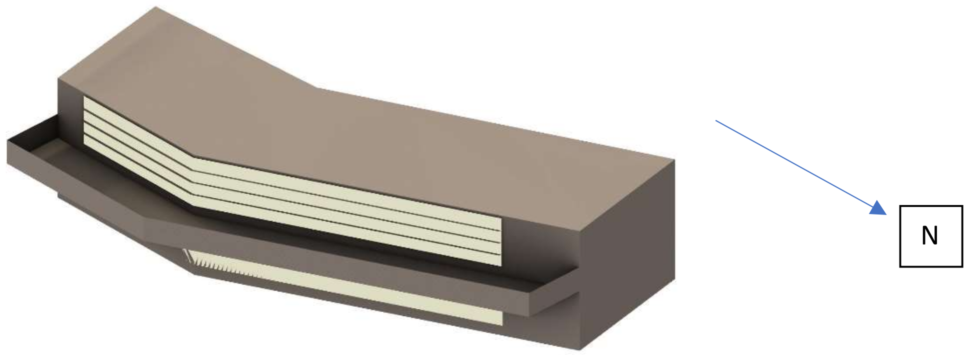
Lighting 6 W/m^2 and Equipment 8W/m^2

Infiltration 0.0001 m^3/s/m^2 façade at 4Pa, ventilation 10l/s/person following CIBSE

Natural ventilation- extra in non-heating season, min. indoor temperature for natural ventilation 20C, 0.8 operable glazing fraction.

Free-running season May- Oct

Heating setpoint 24 C



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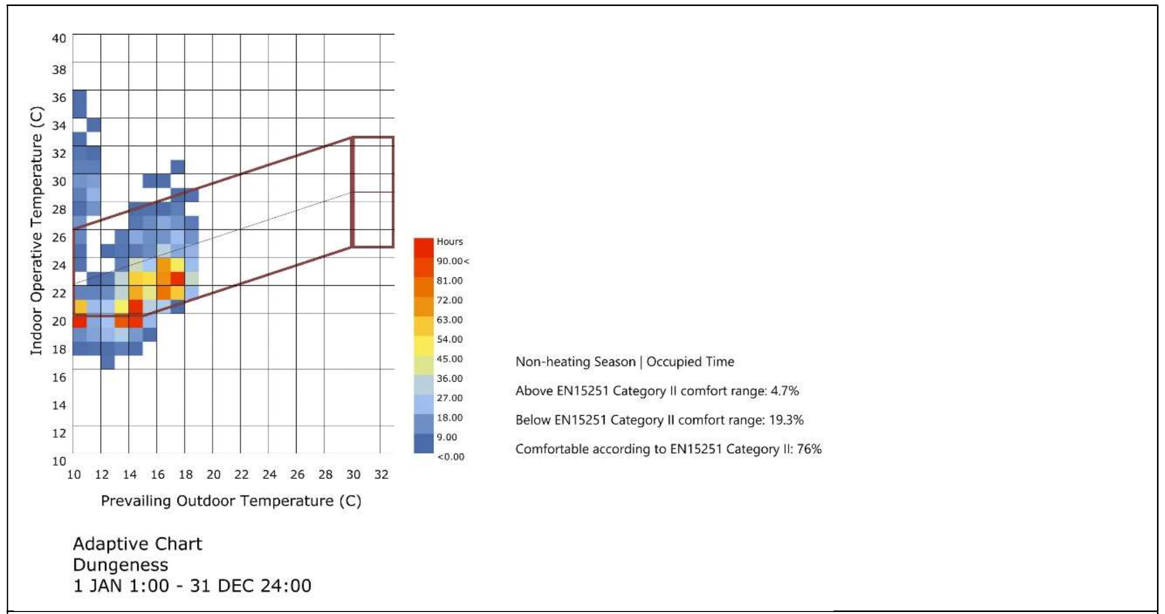
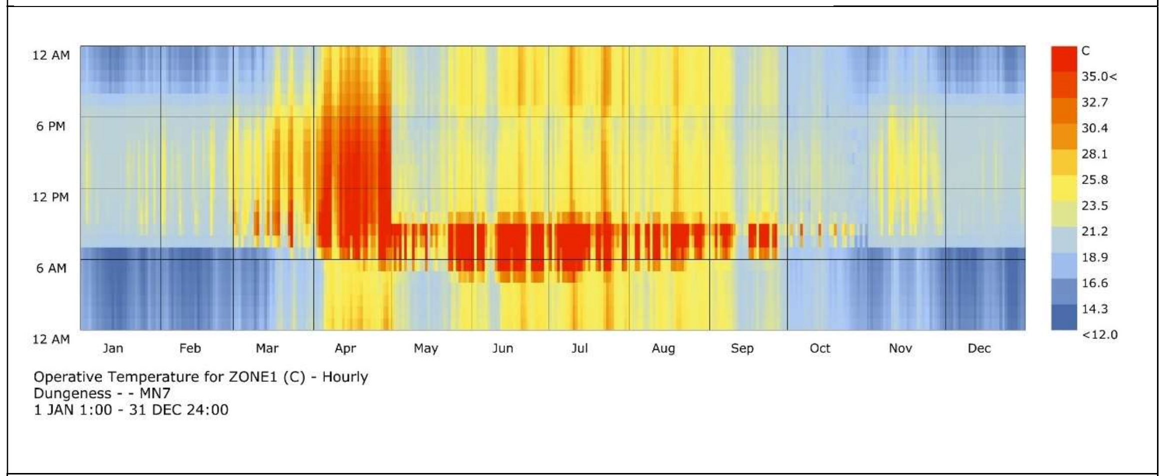
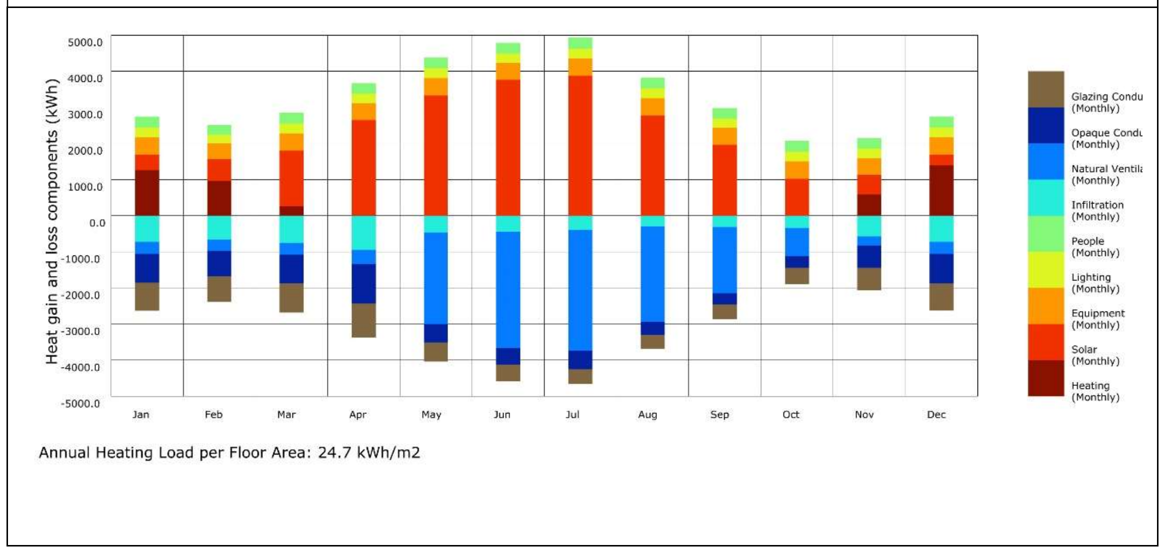






Conclusions:

- Comfort: 76 % within range, with underheating being a more significant problem than overheating.
- Heating load: The most significant heating loads are from solar gains due to large openings.

Iteration 2:

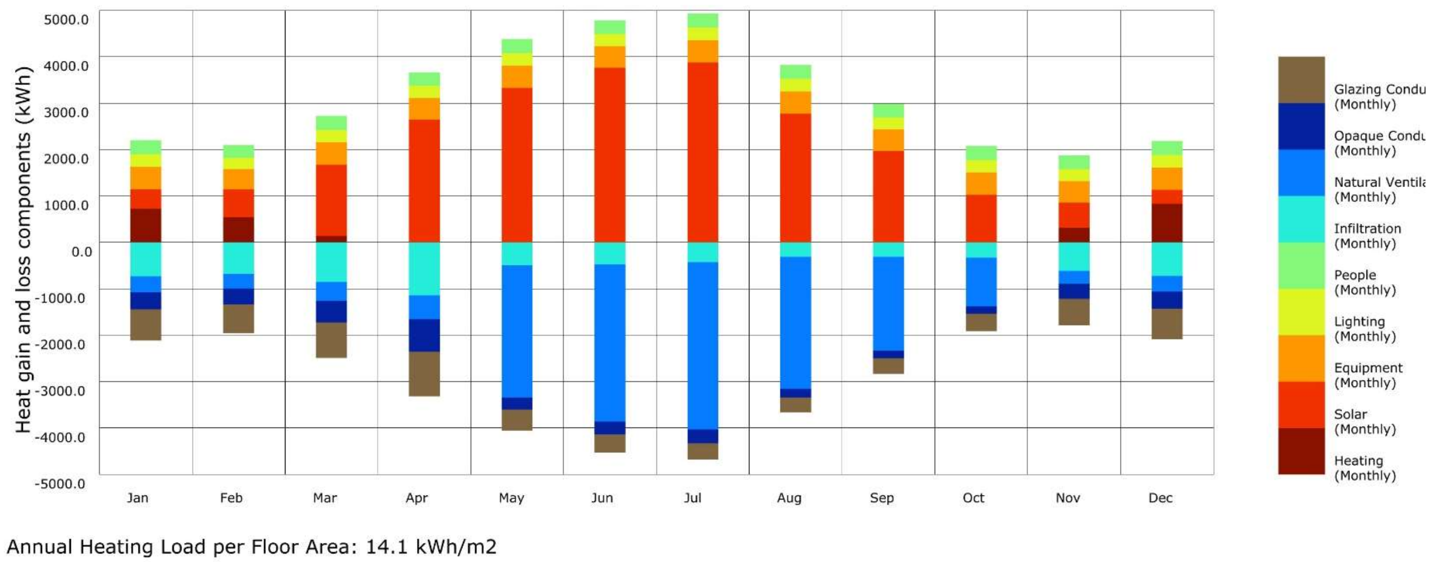
Implementing Passivhaus recommendations of having:

Wall u value 0.1 W/m^2K and window u value 0.8 W/m^2K minimum. This can be achieved through:

- Choosing lower conductivity wood
- Increasing wall thickness
- Increasing insulation in walls, for example using SIPs that are 2 sheets of oriented strand board sandwiching and bonded to insulation such as polyurethane, polystyrene or mineral wool.
- Choosing triple glazed argon, low solar transmittance windows.

New U values after adjustments:

- Wall u value 0.1 W/m^2K
- Roof u value 0.1 W/m^2K
- Floor u value 0.107 W/m^2K
- Window u value 0.75 W/m^2K



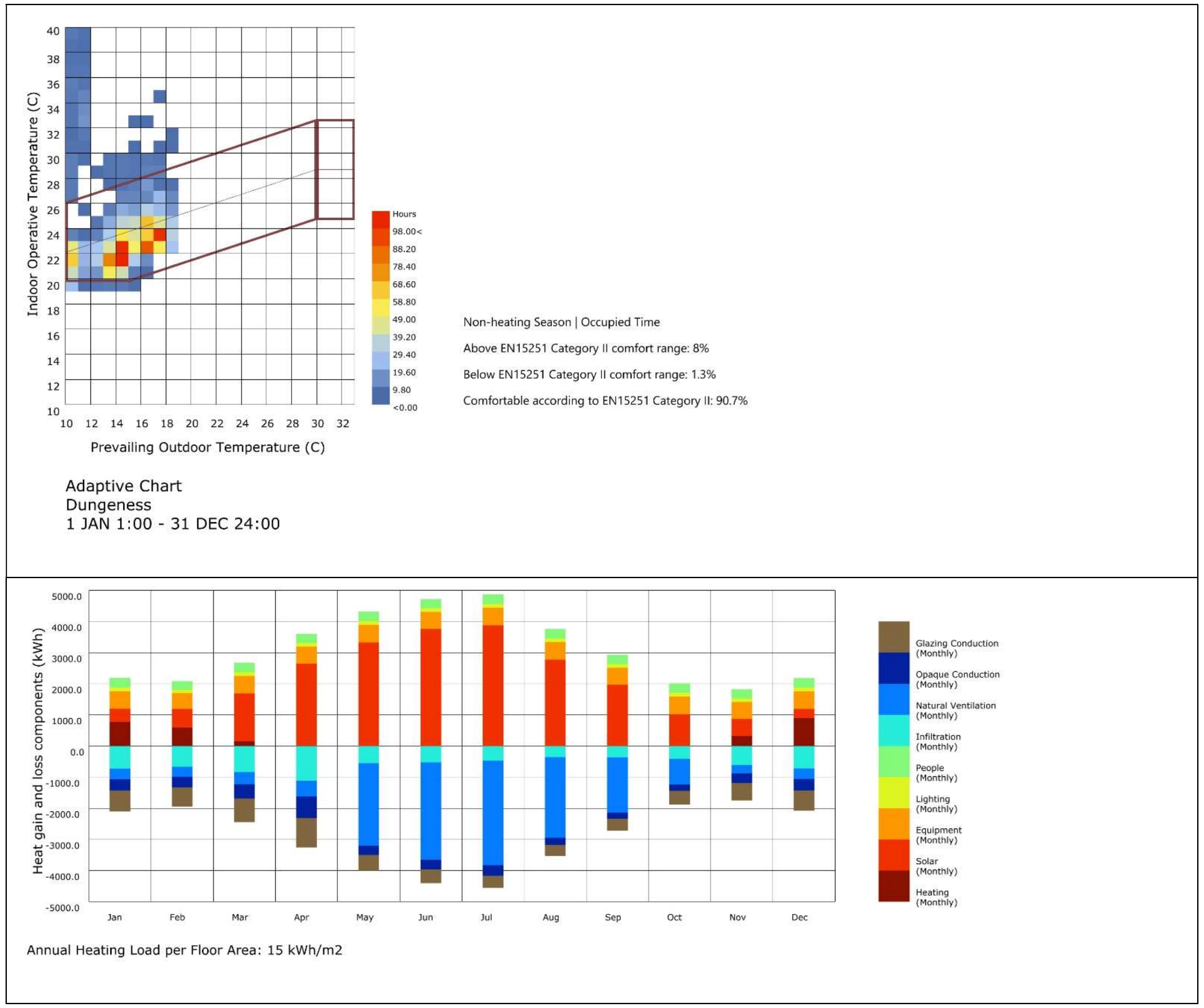
Increasing insulation significantly reduces the annual heating load.

Iteration 3

Reassessing initial assumptions:

Lighting 2.7 W/m^2 and Equipment 9.4W/m^2 based on hotel from ASHRAE 90.1 2013.

Natural ventilation- extra in non-heating season, min. indoor temperature for natural ventilation 22C to reduce temperatures below comfort criteria, 0.8 operable glazing fraction.

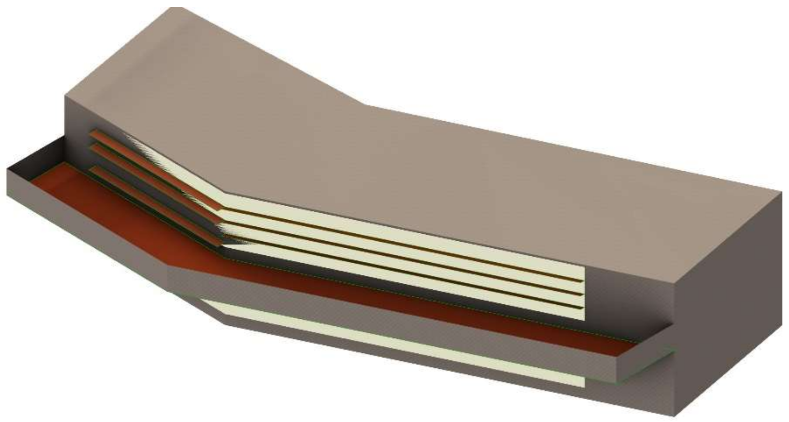


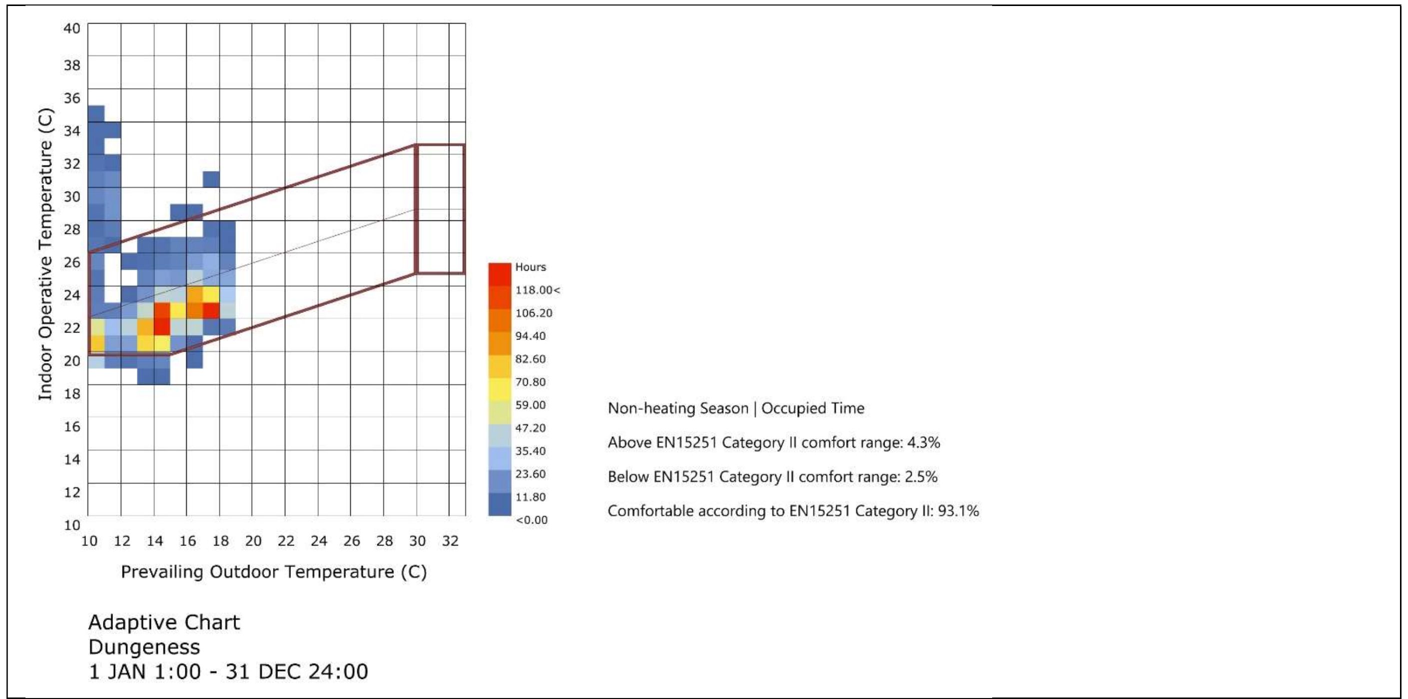
Updating the internal loads as well as the natural ventilation setpoint significantly improves internal comfort up to 90.7% and reduces times below comfort to only 1.3% instead of 19.3 %.

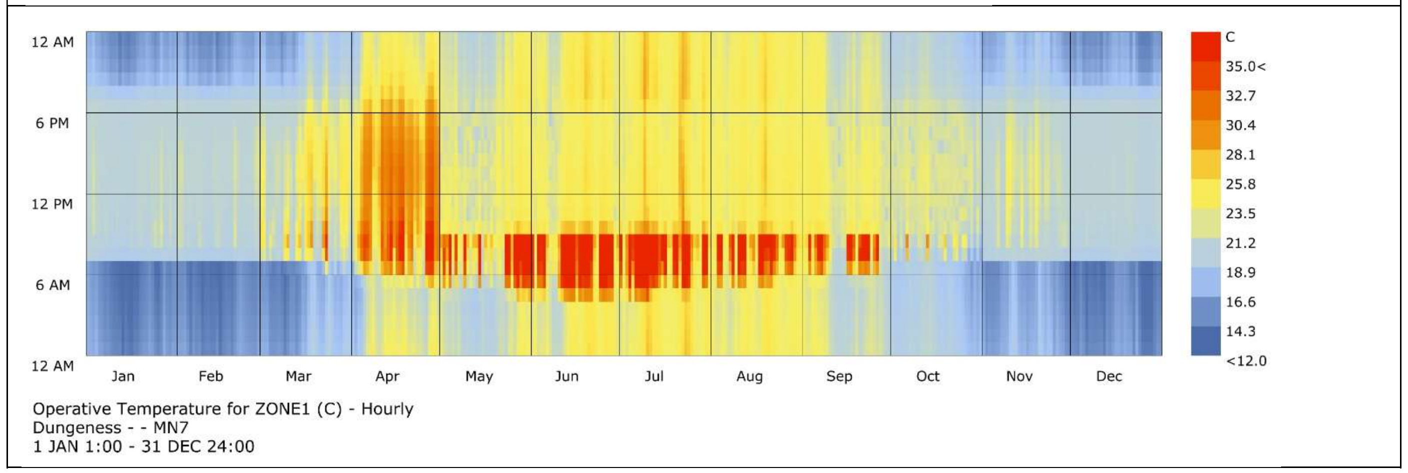
However, this slightly increases the heating load to 15 kWh/m^2.

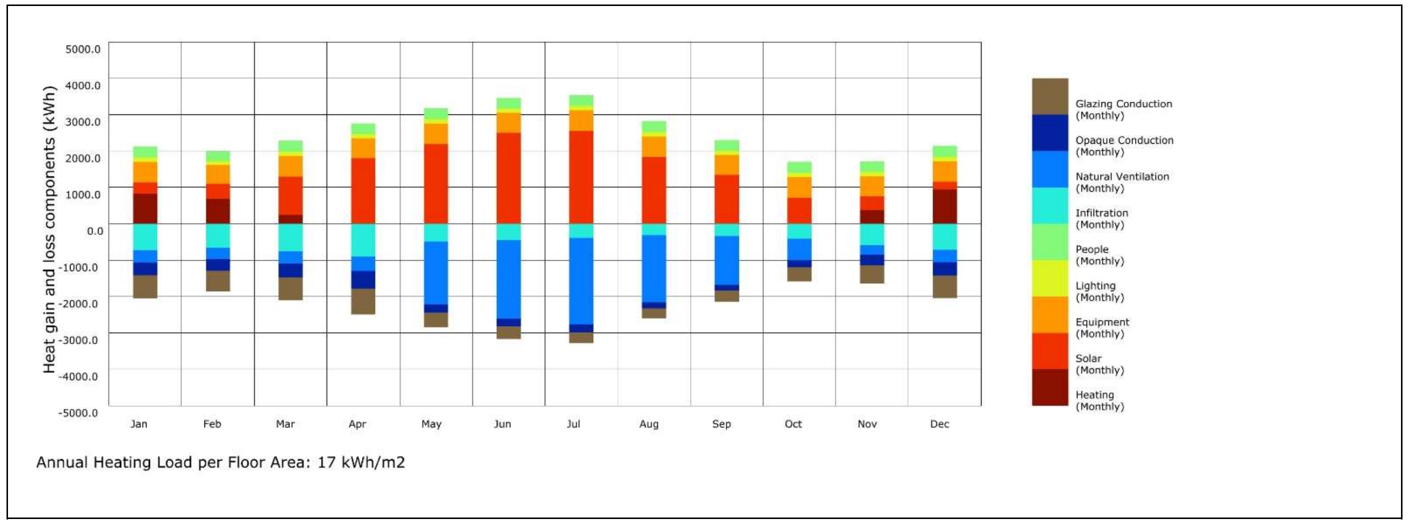
Iteration 4

Activating the horizontal shading (highlighted in red) to reduce the overheating.









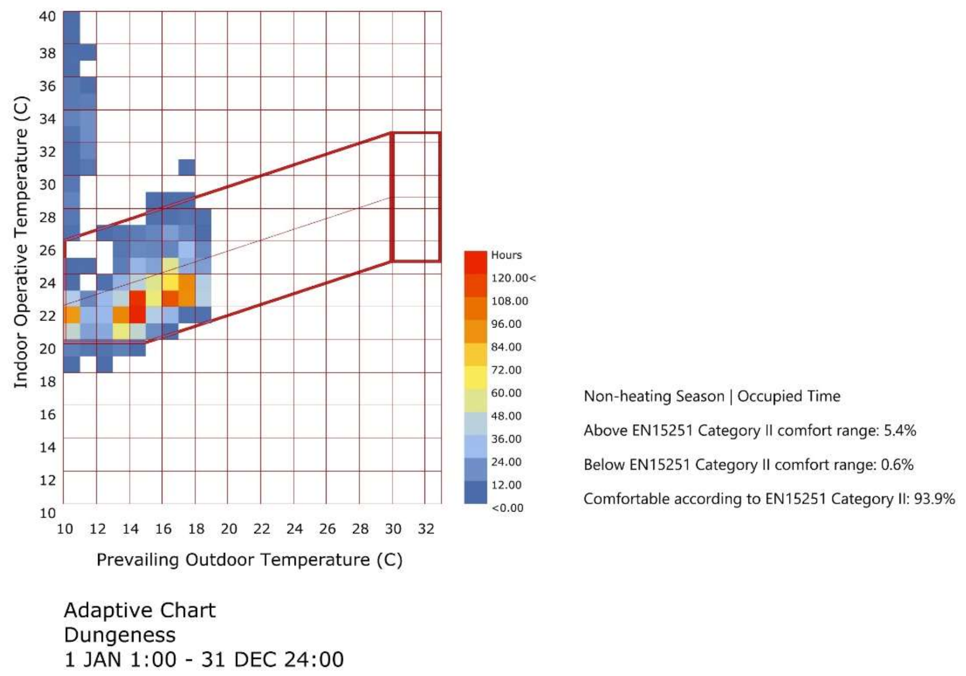
This increases comfort to 93 %, however the heating load has increased due to reduced solar gains. The heat losses due to infiltration can be addressed by making the building more tight, and the glazing heat loss can be reduced through improving glazing, such as using quadrupled glazed windows.

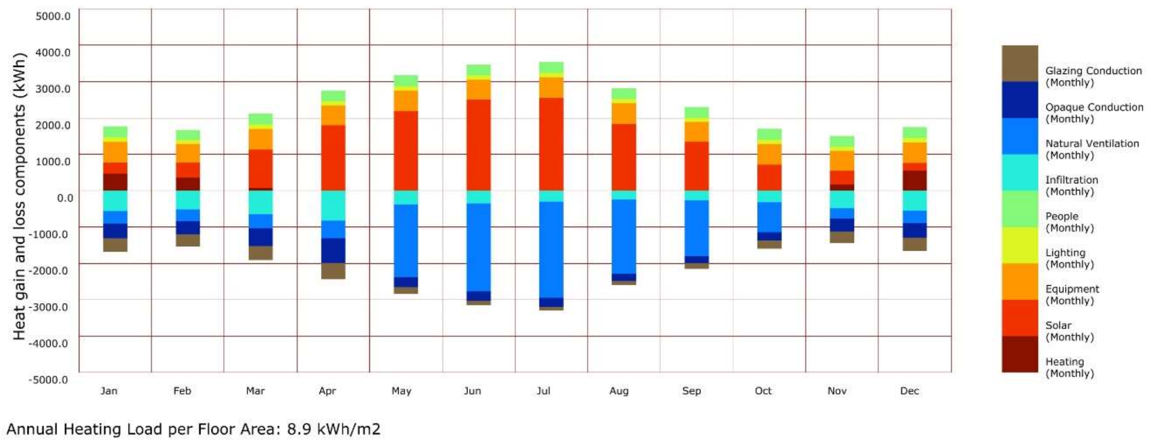
The temperatures are also very high in April and in the morning of the free-running months. This is tackled in iterations 6 and 7 through adjusting the ventilation and occupancy schedules.

Iteration 5

Infiltration 0.000071 m^3/s/m^2 façade following passivhaus guidance.

Window u value 0.4 W/m^2K such as the TREFrorest super low u value unit.



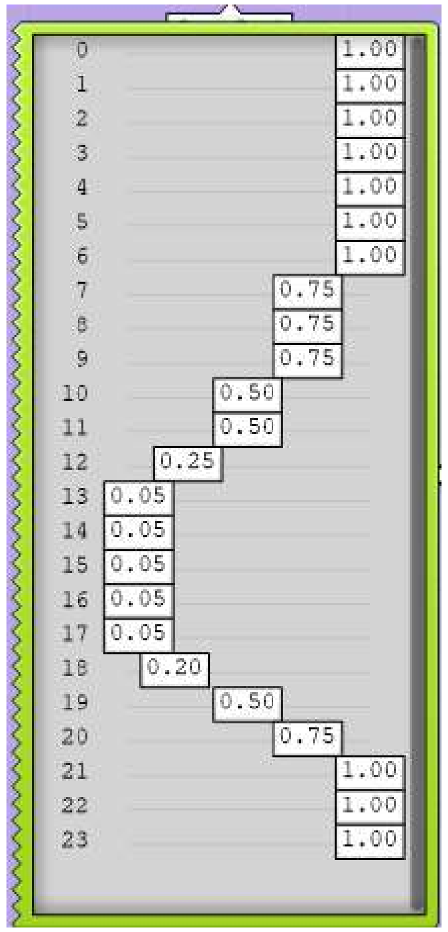
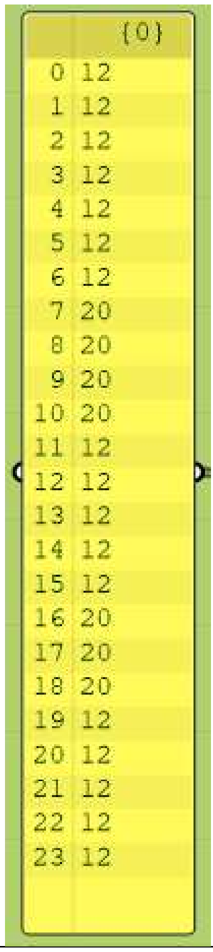


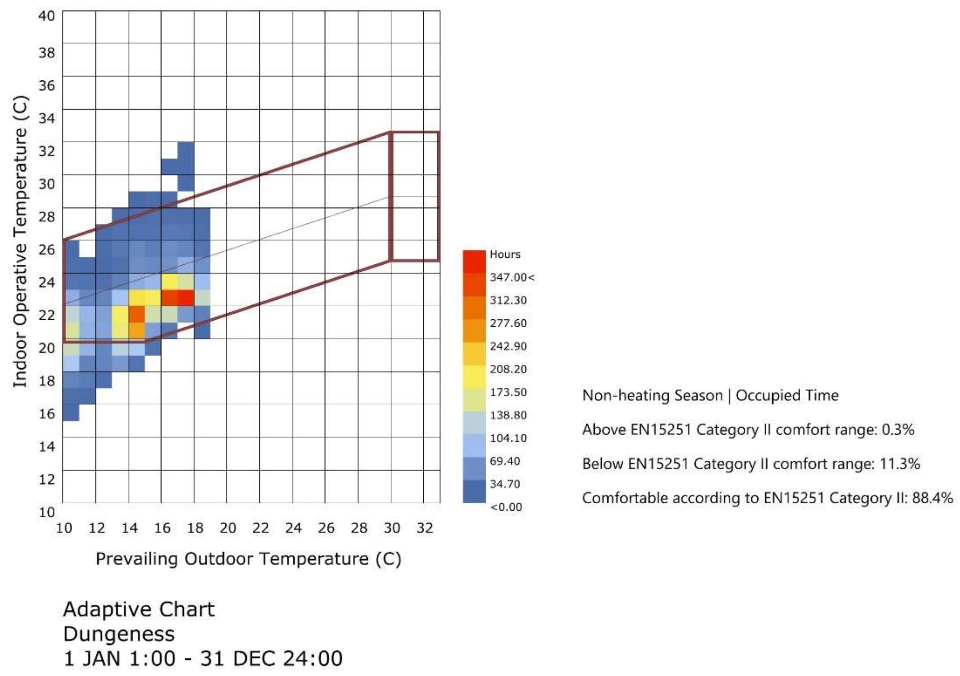
This solution achieves very good thermal performance and comfort for the building as the heat gains and losses through infiltration and glazing are reduced. However, the temperatures observed throughout the iterations are very high in April and in the morning, therefore this is addressed in the final 2 iterations.

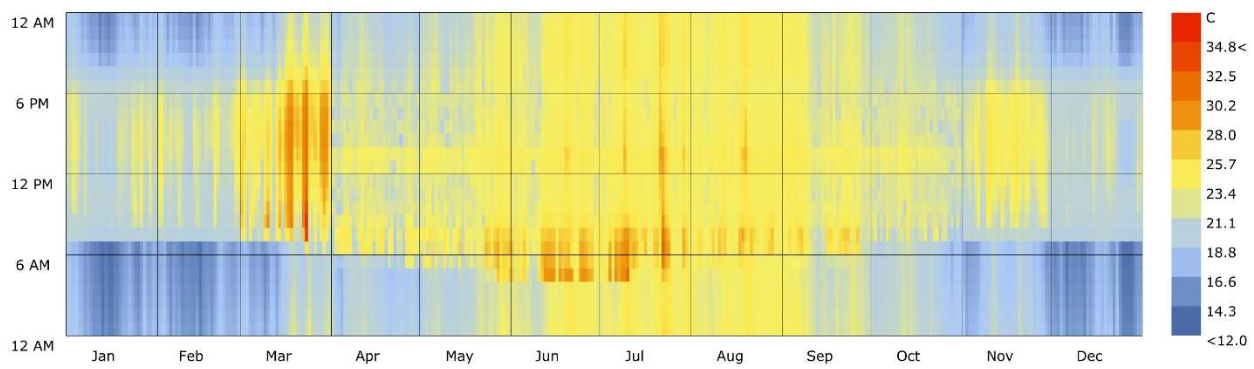
Iteration 6

Ventilation schedule updated to include April – October as high temperatures observed in April

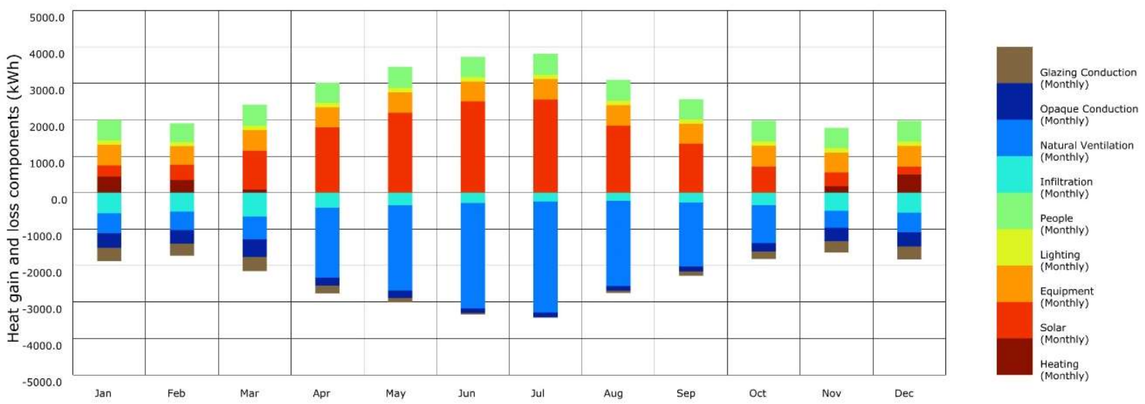
Occupancy and heating schedules also updated to reflect activity in private living area.

occupancy schedule	heating setpoint
	





Operative Temperature for ZONE1 (C) - Hourly
Dungeness - - MN7
1 JAN 1:00 - 31 DEC 24:00



Annual Heating Load per Floor Area: 8.6 kWh/m2

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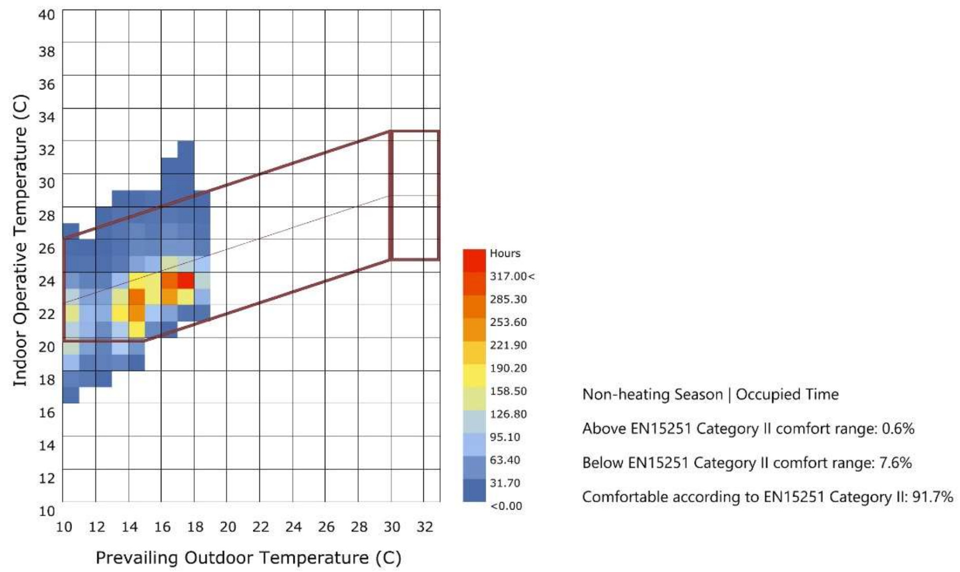
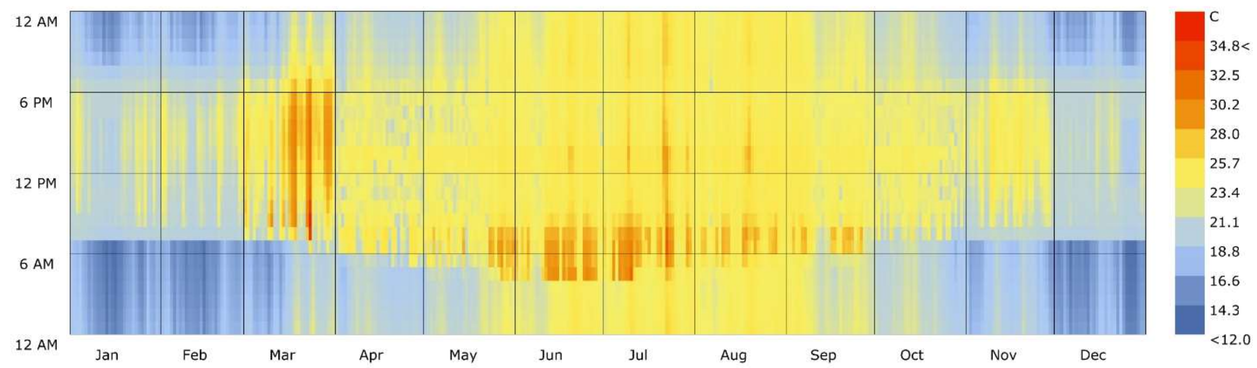
Iteration 7

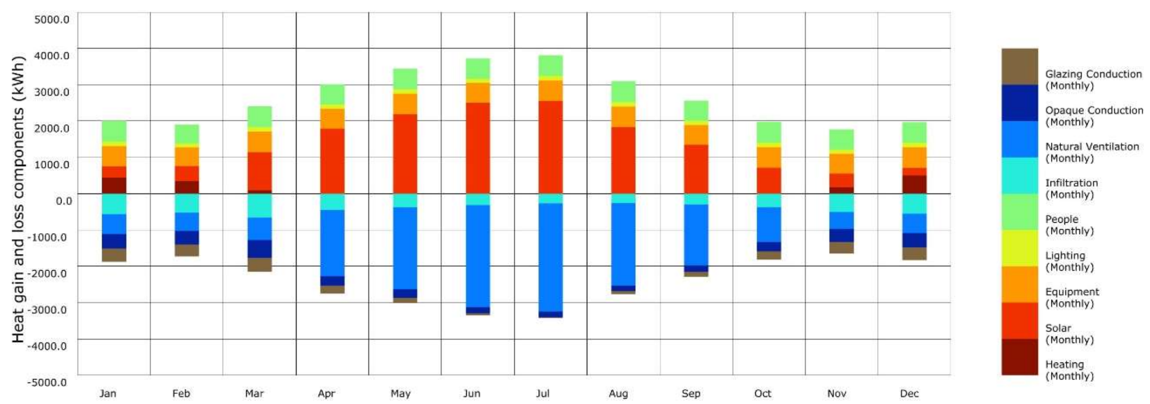
Increase ventilation temperature setpoint from 22C to 23C and reduce operable window area to 0.7 to reduce occupant discomfort due to low temperature.



Adaptive Chart
Dungeness
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for ZONE1 (C) - Hourly
Dungeness - - MN7
1 JAN 1:00 - 31 DEC 24:00



Annual Heating Load per Floor Area: 8.5 kWh/m2

Finally, a summary of the 5 iterations:

Iteration	1	2	3	4	5	6	7
Description	Baseline	Improve building fabric, lower U-values	Update internal gains following ASHRAE, increase min temp. for nat. vent. To 22C to reduce temp. below comfort	Activate shading	Passivhaus infiltration, quadruple glazing	Adjusted ventilation and occupancy schedule	Adjusted ventilation settings
Comfort According to EN15251	76% Mostly **below** comfort	76% Mostly **below** comfort	90.7% Mostly **above** comfort	93.1% Mostly **above** comfort	93.9%	88.4% Mostly **below**	91.7%
Heating load (kWh/m^2)	24.7	14.1	15	17	8.9	8.6	8.5
Challenge, Improvement needed	High fabric gains and losses	Temperature below comfort, high nat. vent. losses	Lower ventilation losses mean higher heating load	Higher heating load due to lower solar gains and high losses from infiltration and glazing	Very high morning temperature and April temperature	Cold temperature below thermal comfort	

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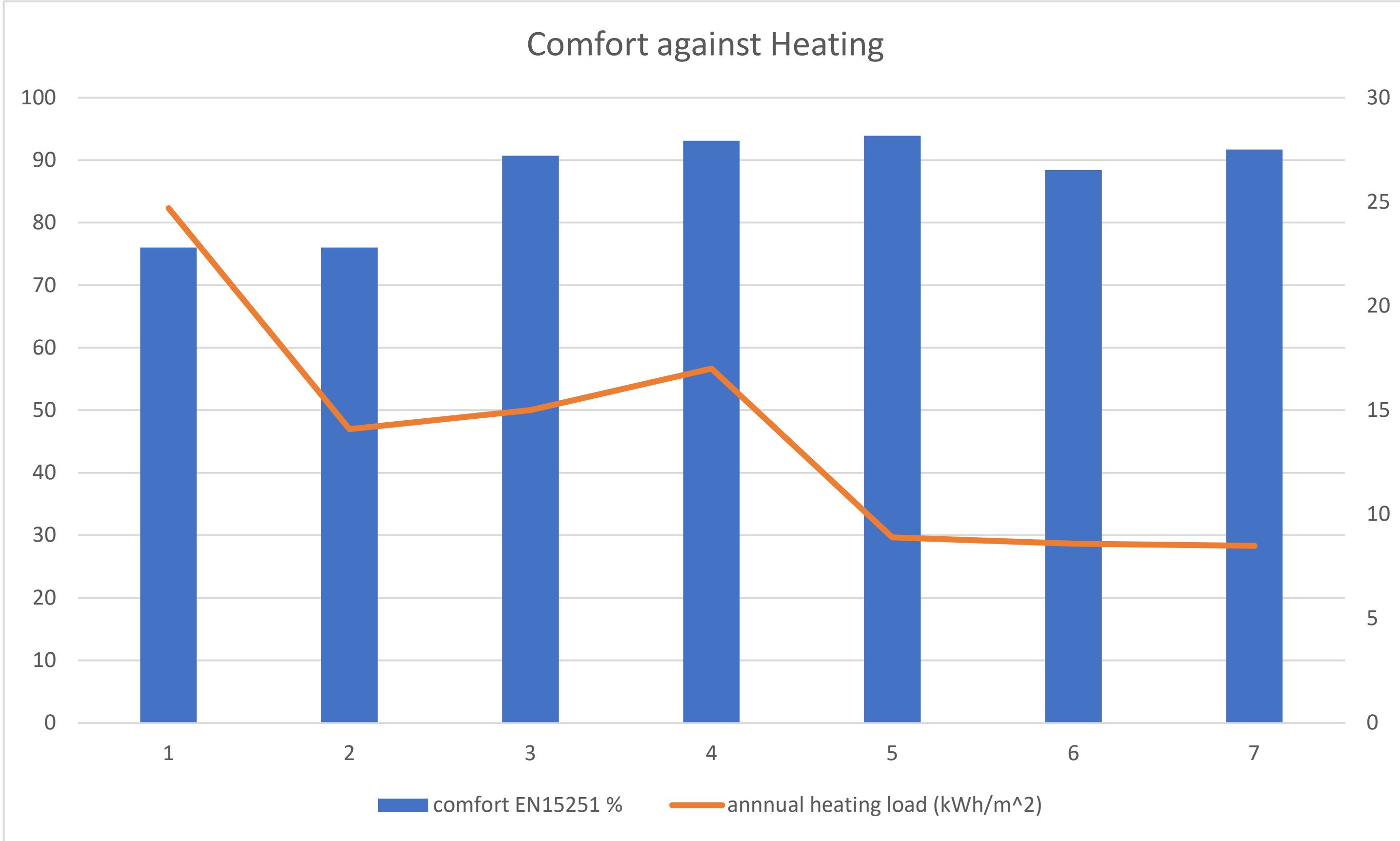

This graph shows how iteration 7 has a good balance between high comfort and low heating demand.

As this simulation is only of one space of the building (the Eastern private living area), other environmental strategies implemented in other areas are mentioned:

- Use of the light shelf for the north glazing in the gallery space, as well as cross ventilation.
- Acoustic separation for the artists' living space for privacy: Acoustic Foam Tiles for sound dampening for their acoustic properties and as they have good fire ratings and can be made from recycled plastics and other eco-friendly materials.
- Horizontal shading system for the east facades to protect from low sun angles.
- Gabion walls providing high thermal mass for the front elevation.
- Ceiling openings to allow for cross-ventilation where the plan is deep and width> 5*height, for example in the central gallery space.
- Extract ventilation in dark room and chemical storage spaces as having windows is not suitable. This is to maintain darkness and prevent damage to chemicals and film from light.
- UV coating on gallery glass to protect exhibits from UV damage

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Project 2: Building Project

Dungeness

Design Practice 1

Studio 1