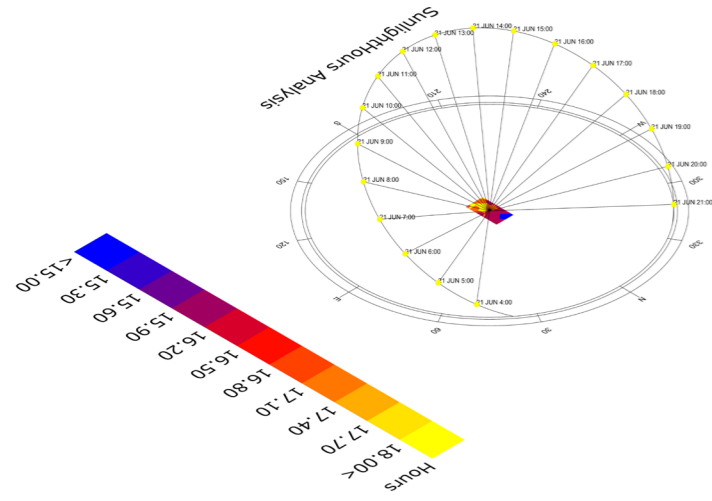
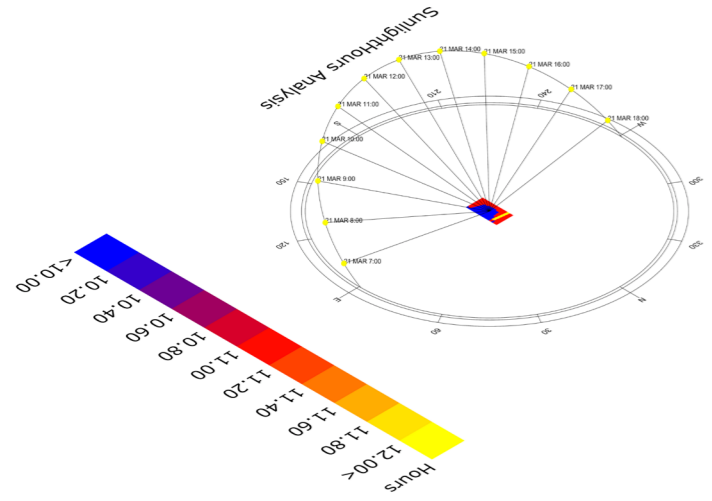
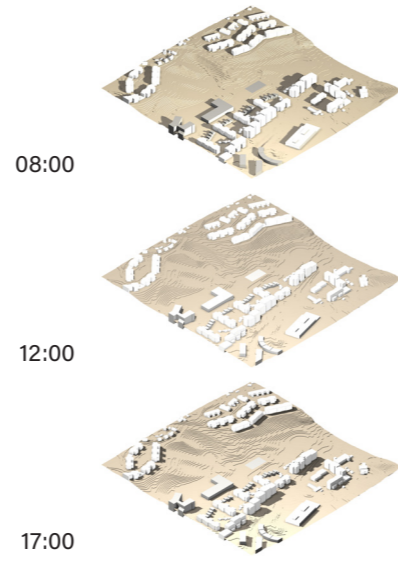


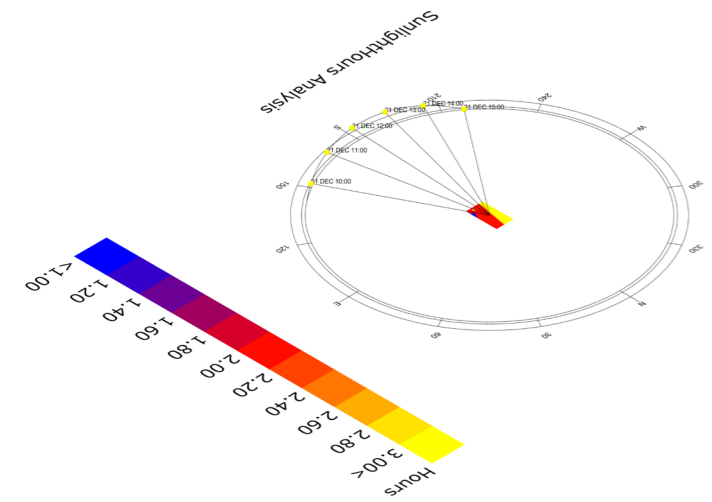
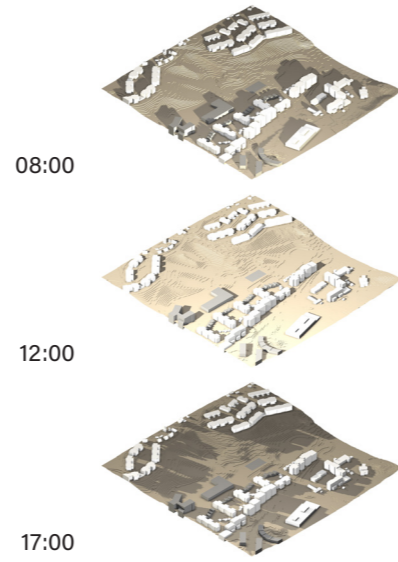
Daylight calculations



Sun path diagram - June 21st
Sunlight hours includes obstructions on site

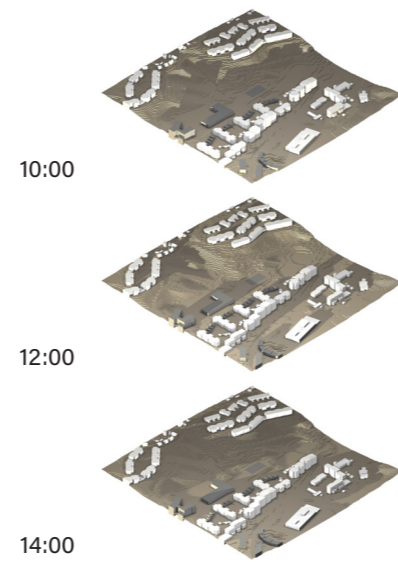


Sun path diagram - March 21st

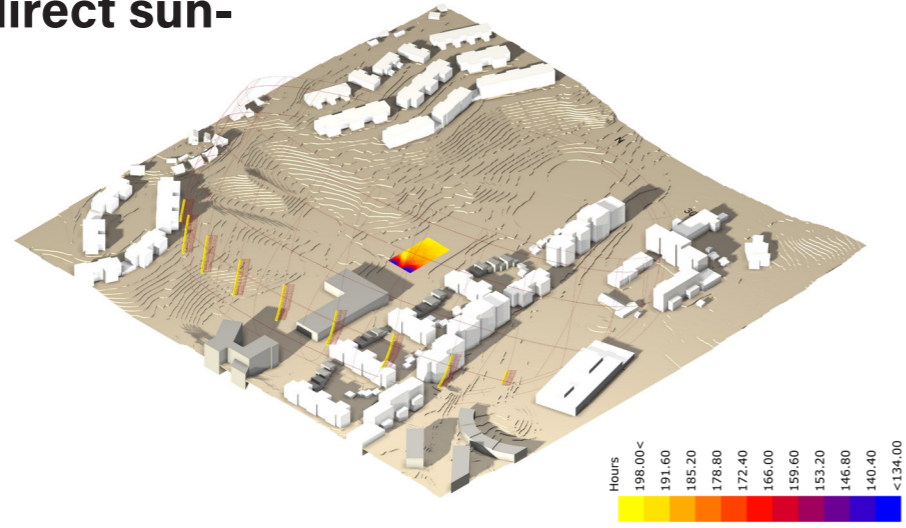


Sun path diagram - December 21st

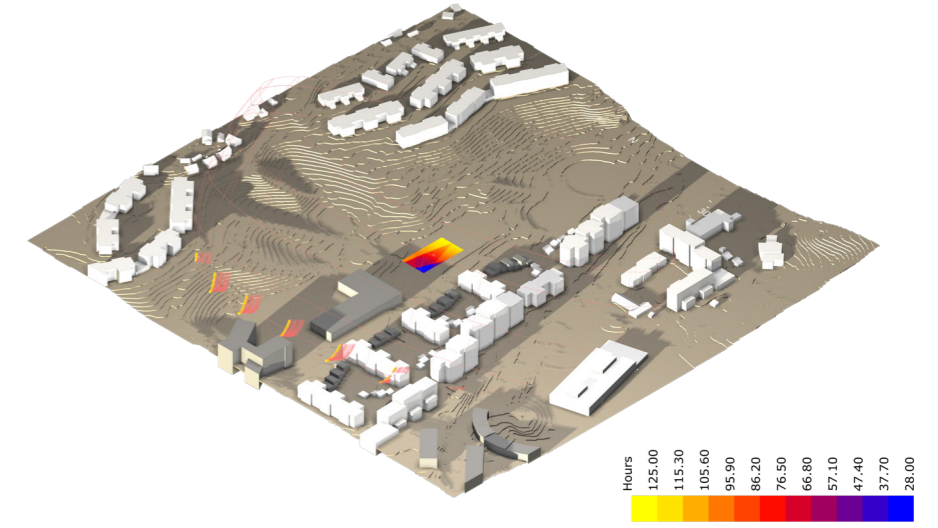
Note: Sunlight hours includes obstructions on site



Hours of potential direct sunlight on site

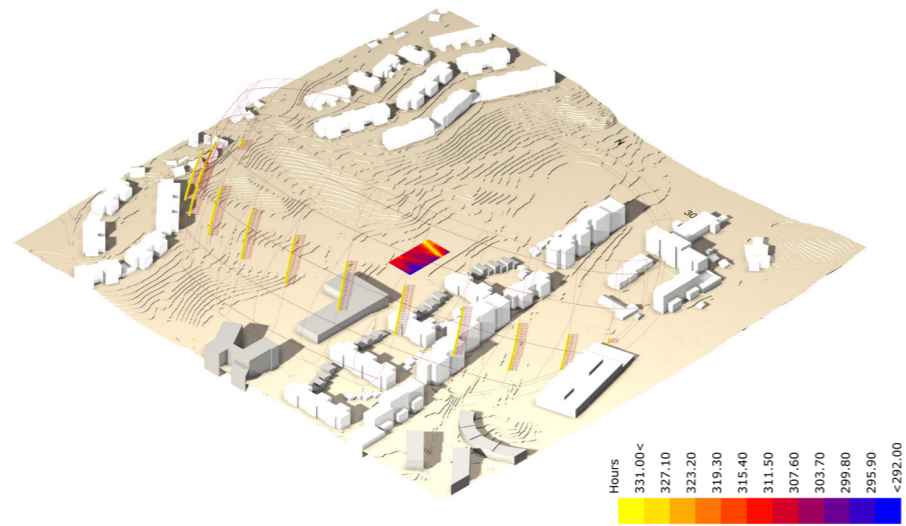


Rendering at February 21st - 12:00
Average of 181 sunlight hours of potential direct sunlight on site

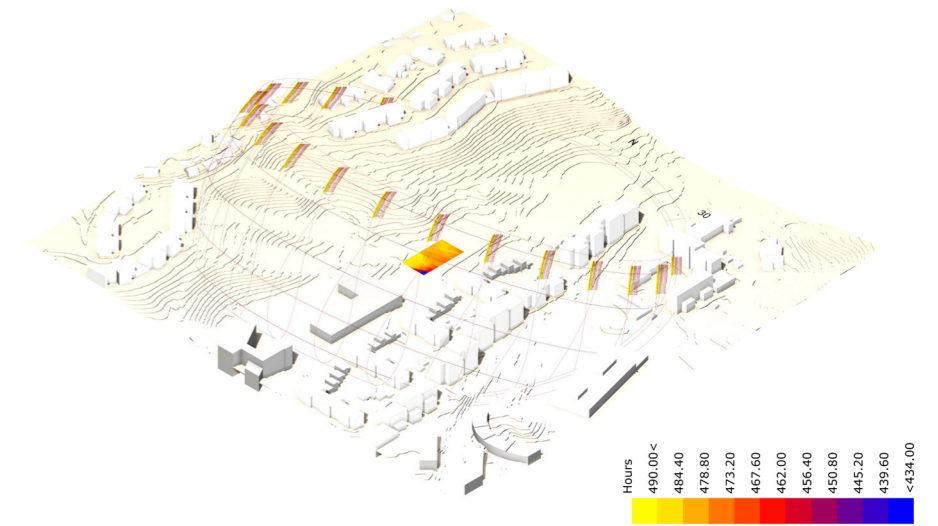


Rendering at January 21st - 12:00
Average of 86 hours of potential direct sunlight on site

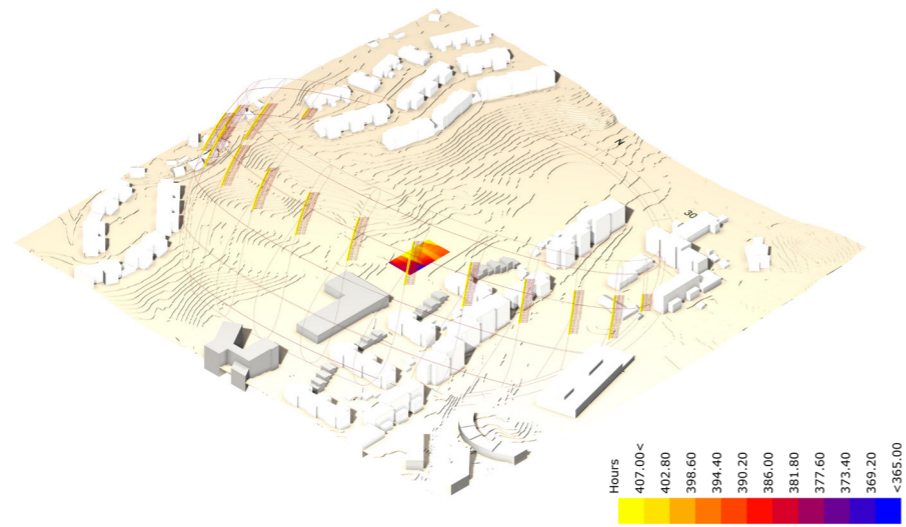
- Januar 86
- Februar 181
- Mars 308
- April 391
- Mai 478
- June 489
- Juli 488
- August 436
- September 329
- Oktober 243
- November 124
- Dezember 74



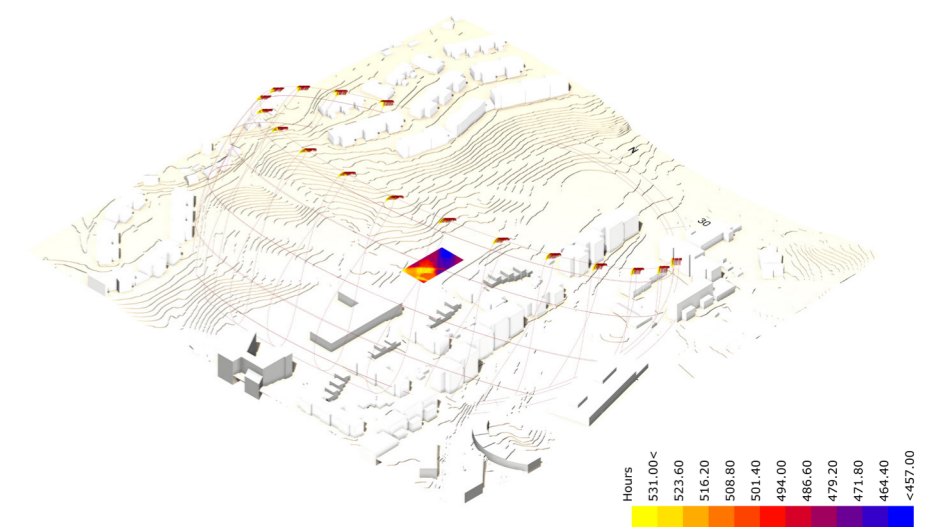
Rendering at March 21st - 12:00
Average of 308 sunlight hours of potential direct sunlight on site



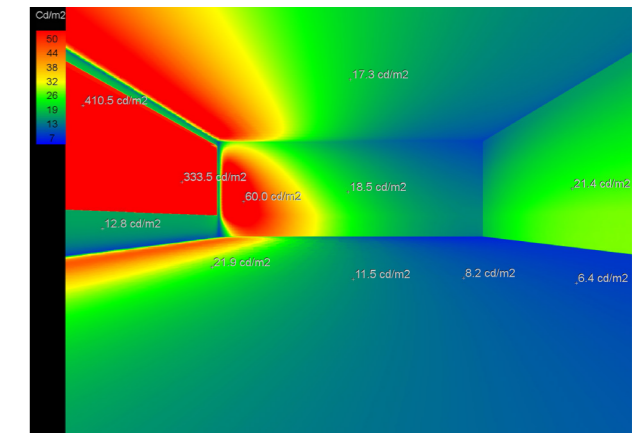
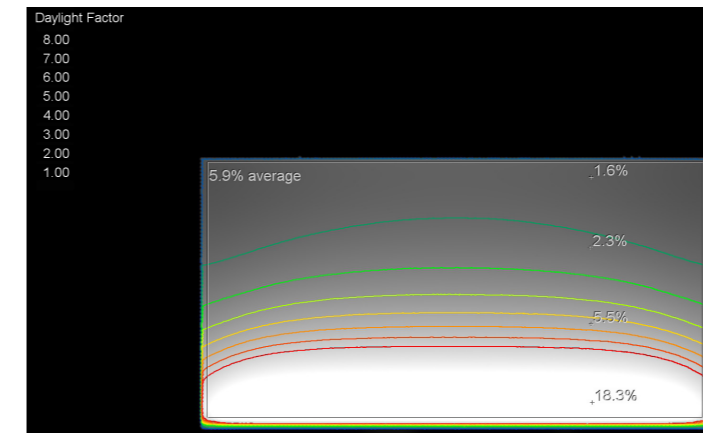
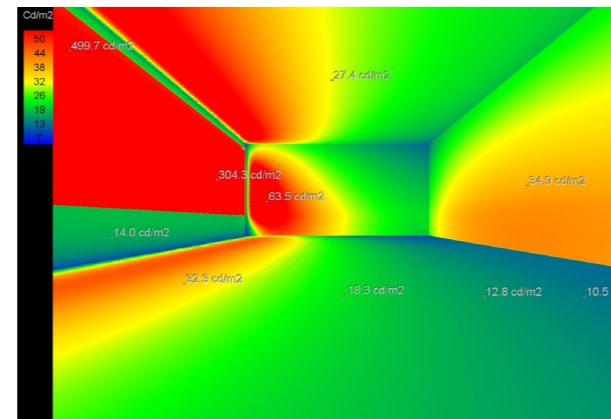
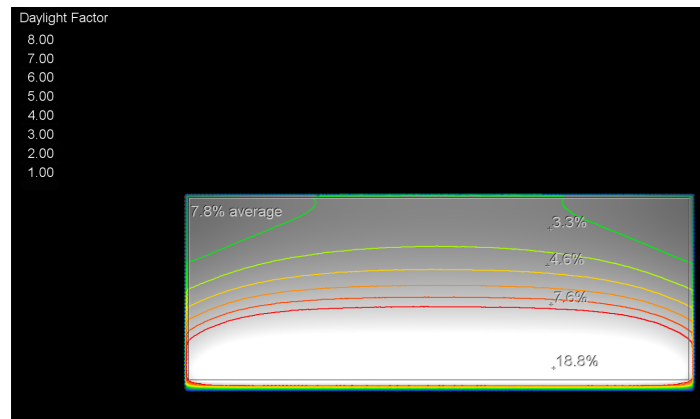
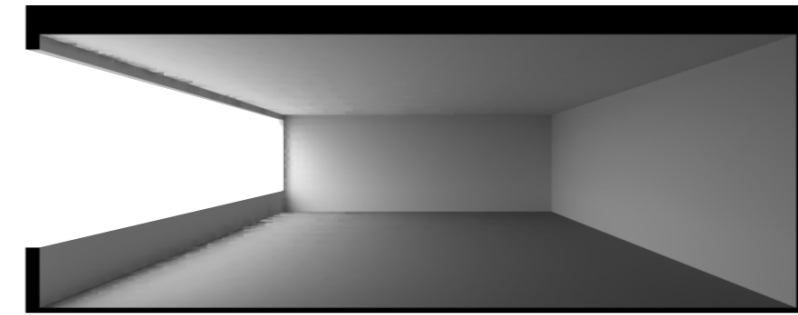
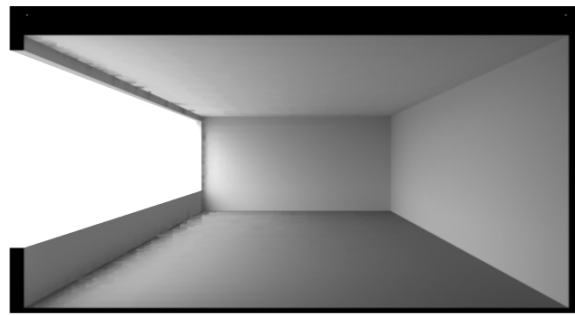
Rendering at May 21st - 12:00
Average of 478 sunlight hours of potential direct sunlight on site



Rendering at April 21st - 12:00
Average of 391 sunlight hours of potential direct sunlight on site



Rendering at June 21st - 12:00
Average of 489 sunlight hours of potential direct sunlight on site



DF% - Sidelit room

Mean	7.78
Median	5.72
Minimum	2.03
Maximum	18.87
Uniformity 1	0.26 (min/mean)
Uniformity 2	0.11 (min/max)

Room dimensions: (LxWxH) 47x18x9m

Window dimensions: (LxW) 46x6.5m

Underkant vindu: 2m

Glass to Floor Area Ratio (GFAR): 35.5%

Light transmittance: 68%

Sky condition CIE overcast sky

In this example the depth of the room is twice the ceiling height. A normal recommended ratio for a daylit space with light from only one side.

The size of the window is maximized. Raised 2 meters above the floor to make the glass area most efficient. View out is lost.

DF% - Sidelit room

Mean	5.75
Median	3.44
Minimum	1.20
Maximum	18.87
Uniformity 1	0.21 (min/mean)
Uniformity 2	0.06 (min/max)

Room dimensions: (LxWxH) 47x25x9m

Window dimensions: (LxW) 46x6.5m

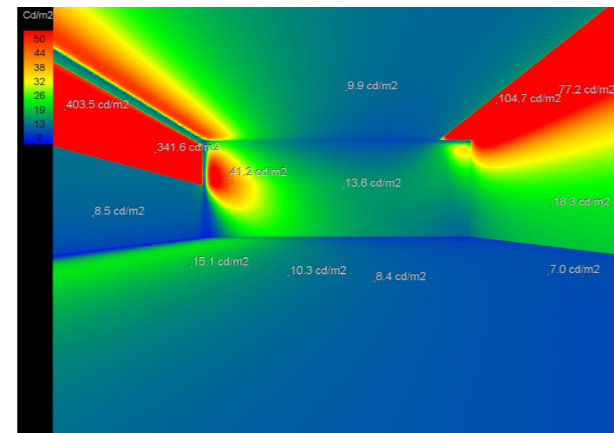
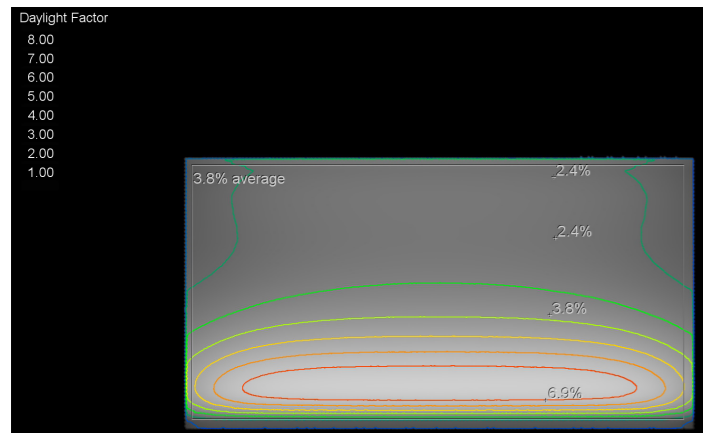
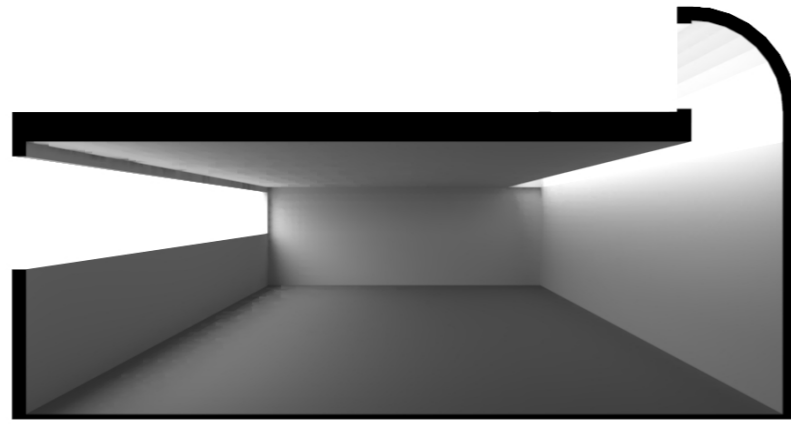
Underkant vindu: 2m

Glass to Floor Area Ratio (GFAR): 25.5%

Light transmittance: 68%

Sky condition CIE overcast sky

In this example the depth of the room is 2.77 times the ceiling height. The DF uniformity has dropped. That is also for the



DF% - Sidelit room

Mean	3.77
Median	2.85
Minimum	1.45
Maximum	7.88
Uniformity 1	0.38 (min/mean)
Uniformity 2	0.18 (min/max)

Room dimensions: 47x25x9m
(LxWxH)

Window dimensions: 46x6.5m
(LxW)

Underkant vindu: 2m

Glass to Floor Area Ratio (GFAR): 25.5%

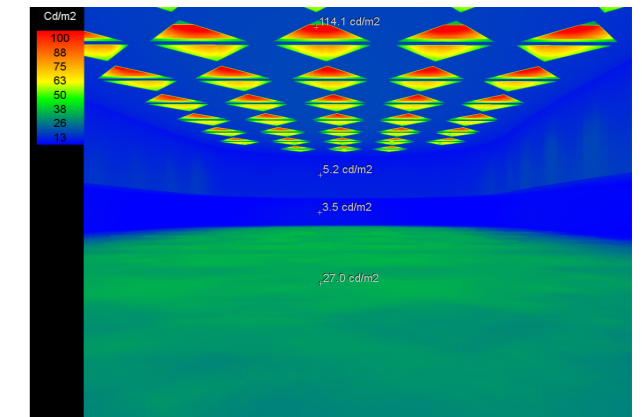
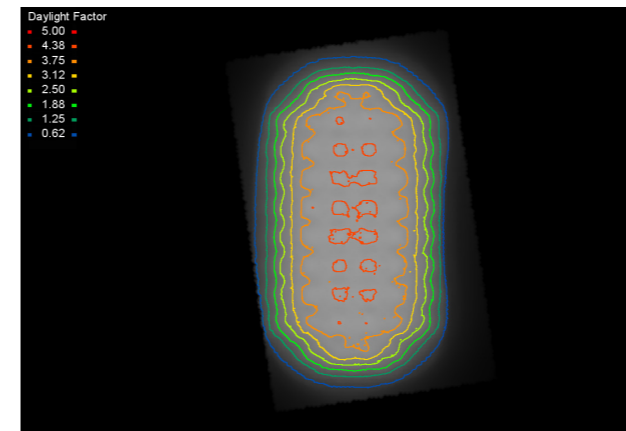
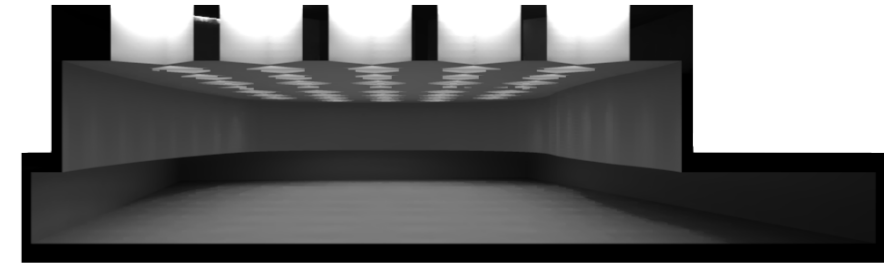
Light transmittance: 68%

Sky condition CIE overcast sky

In this example the glass to floor ratio is the same, but the daylight is also now distributed from a roof monitor directed towards north.

The DF uniformity has increased quite drastically. The average daylight factor has dropped. The uniformity is although not close to the recommended uniformity level of 0.7 for electric lighting.

Studies of reference projects



DF% - Toplit room
Falkonergården -
Falkoarkitekter

Mean	3.81
Median	4.02
Minimum	1.15
Maximum	4.66
Uniformity 1	0.3 (min/mean)
Uniformity 2	0.25 (min/max)

Room dimensions: 45x25x9m
(LxWxH)

Window dimensions: 3x3m (coffer opening)
(LxW)

Underkant vindu: Skylights depth - 2.8m

Glass to Floor Area Ratio (GFAR): 30.5%

Light transmittance: 60% Opaque glass

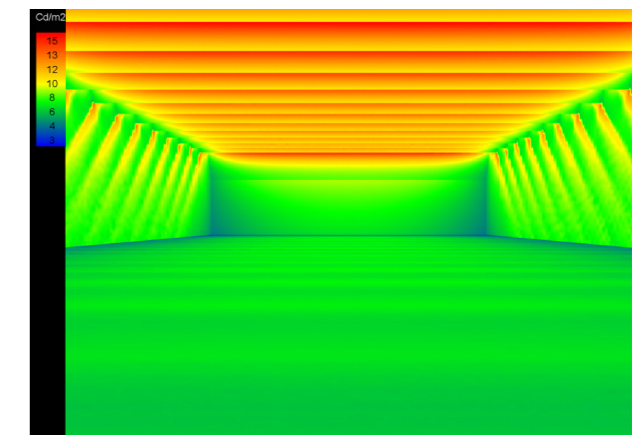
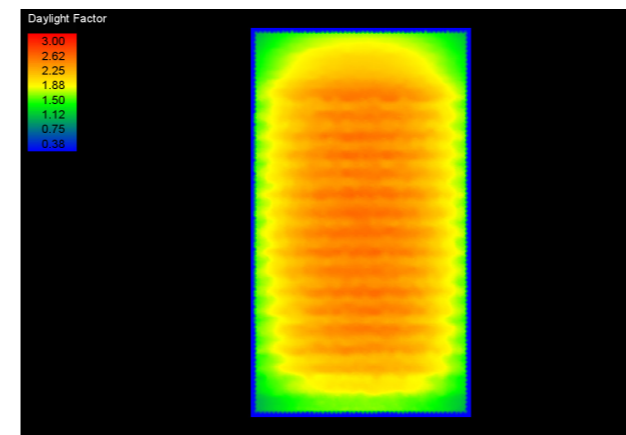
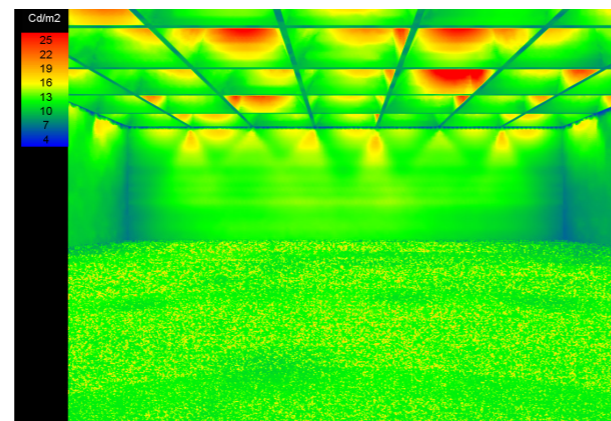
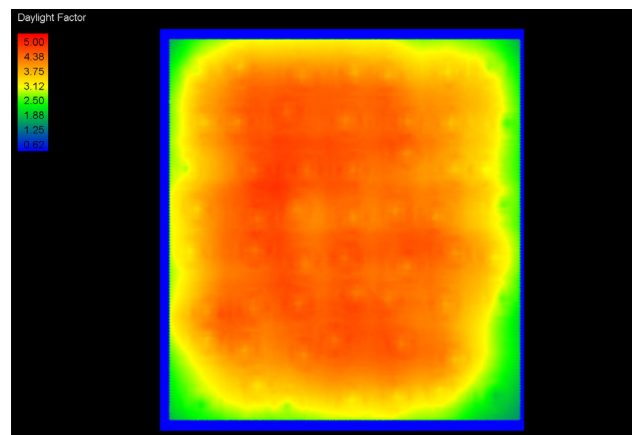
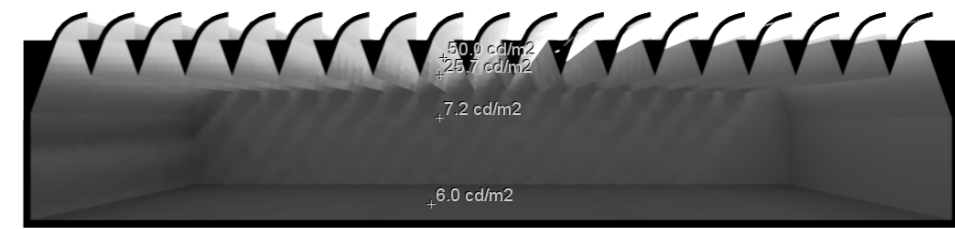
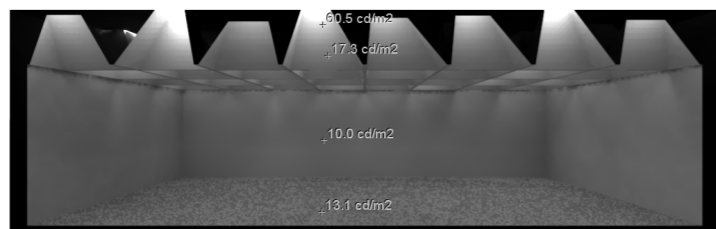
Sky condition CIE overcast sky

The principle of Falkonergården was used to look how it would work in a 25x45m sports hall. The span of the diagonal beams becomes 45m, compared to 25m i Falkonergården.

Falkonergården is a smaller hall size measuring 28x18m

Some direct sunlight fall into the hall space.





DF% - Toplit room
School in Claus - Dietrich
architecten

Mean	3.66
Median	3.84
Minimum	1.42
Maximum	4.56
Uniformity 1	0.39 (min/mean)
Uniformity 2	0.31 (min/max)

Room dimensions:
(LxWxH) 27x29x7m

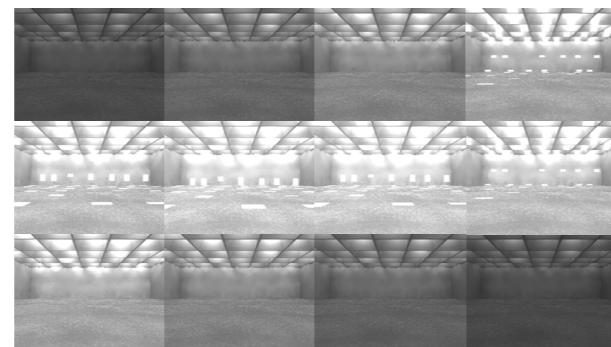
Window dimensions:
(LxW) 1,44m²

Underkant vindu: Skylights depth - 2.4m

Glass to Floor Area Ratio (GFAR): 20.3%

Light transmittance: 68% Opaque glass

Sky condition CIE overcast sky



Annual visualisation of sunlight distribution at 21st each month at 12:00



DF% - Toplit room
Lenbachhaus Museum -
Fosters architects

Mean	1.92
Median	1.99
Minimum	0.87
Maximum	2.46
Uniformity 1	0.45 (min/mean)
Uniformity 2	0.35 (min/max)

Room dimensions:
(LxWxH) 45x25x9m

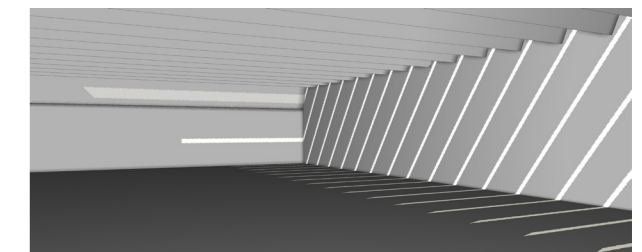
Window dimensions:
(LxW) 1x25m

Underkant vindu: Skylights depth - 2.9m

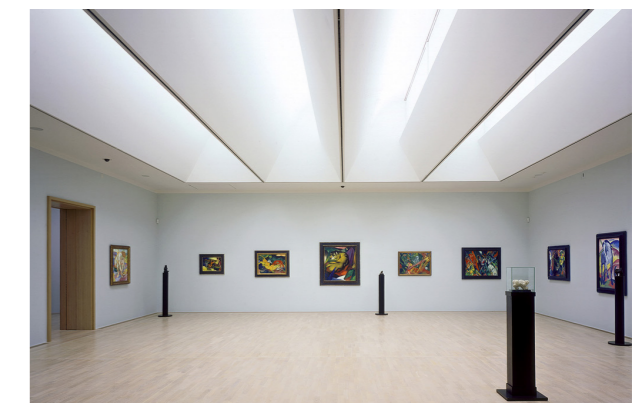
Glass to Floor Area Ratio (GFAR): 42.2%

Light transmittance: 68%

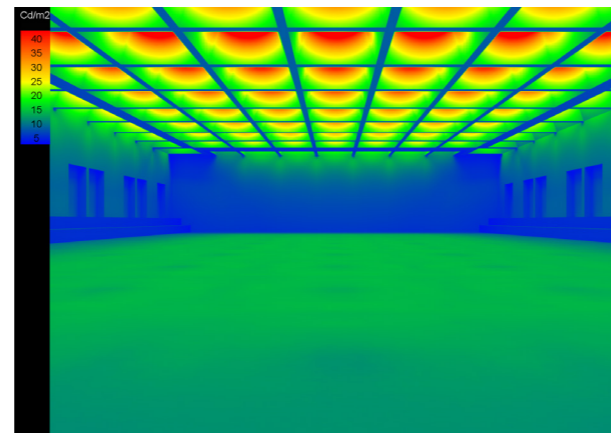
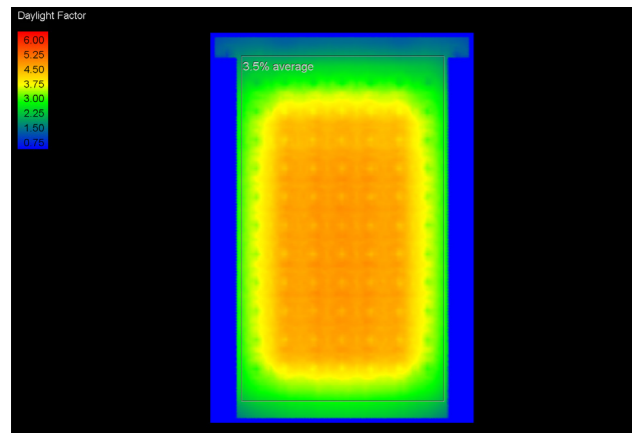
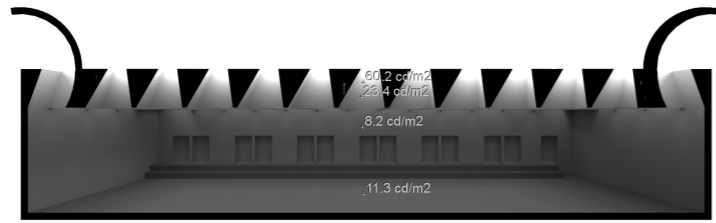
Sky condition CIE overcast sky



Direct sunlight appears around half an hour in the early morning from 08:07-08:35 21st of June. Lack of precision in drawing the 3D model may be the reason for the direct sunlight.



Process calculation studies



DF% - Model study
Sun scoop #1

Mean	3.52
Median	3.71
Minimum	1.29
Maximum	4.51
Uniformity 1	0.37 (min/mean)
Uniformity 2	0.29 (min/max)

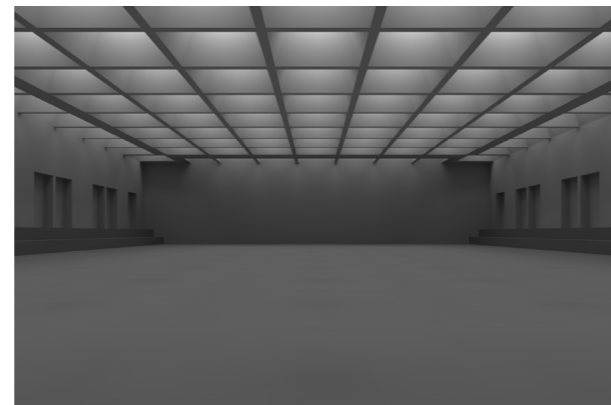
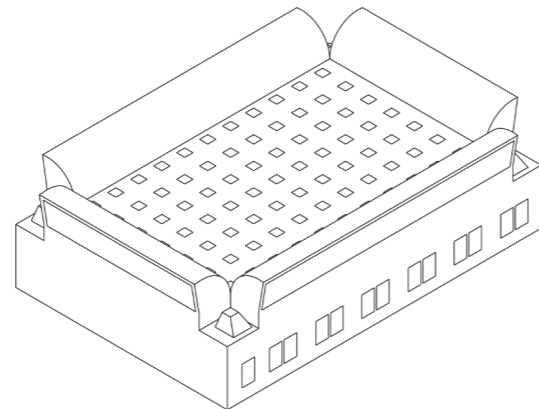
Room dimensions:
(LxWxH) 45x30x7m

Window dimensions:
(LxW) Skylights: $77 \times 1,44 \text{ m}^2 = 110.9 \text{ m}^2$
Sun scoops: $2 \times 37 \times 3.6 \text{ m} + 2 \times (21.7 \times 3.6 \text{ m}) = 422 \text{ m}^2$
Underkant vindu: Skylights depth - 2.6m

Glass to Floor Area Ratio
(GFAR): $533/1350 = 39.4\%$

Light transmittance: 68%

Sky condition CIE overcast sky



View towards south - 12:00 21 Mars

Comments:

The organization of one scoop for each cardinal direction does not quite work as intended. The idea was to reflect the sun's transition and reflected light quality throughout the day. But the transition is not clear enough.

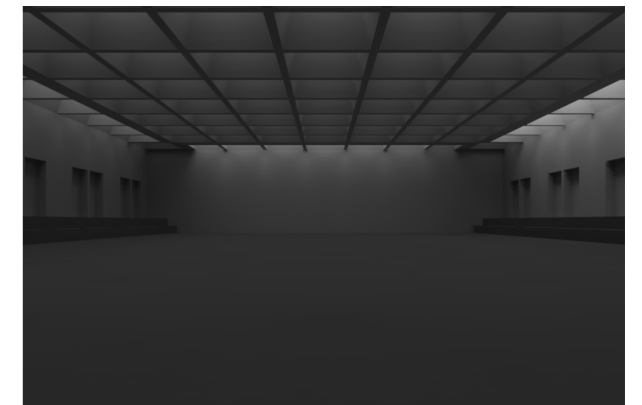
To orient sun scoops only to the west and east will give a clearer differentiation in giving clearer reference to time of day by shifting the focus between morning and afternoon sunlight.

Vertical windows are not included in the calculation.

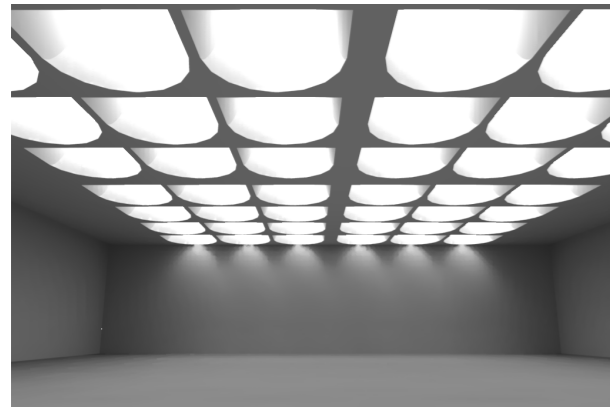
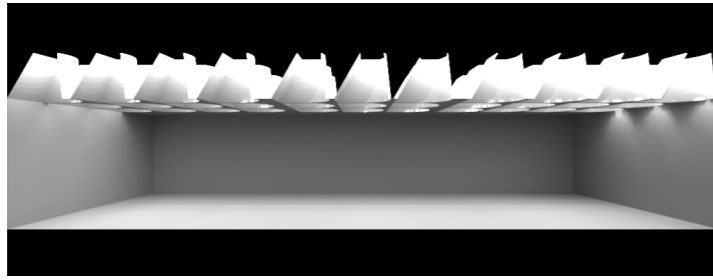
A suncatcher would distribute direct sunlight equally on west and east wall. But I think it is nicer to be able to read the difference.



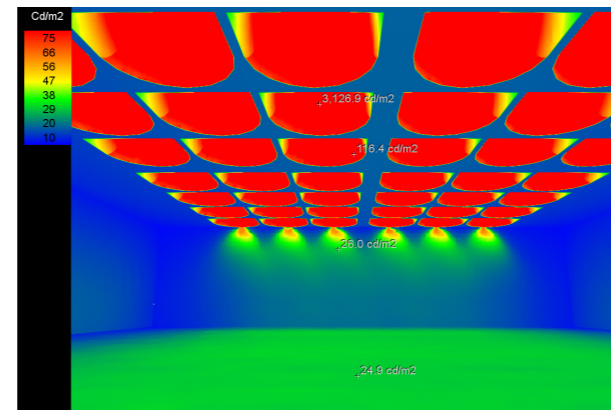
View towards south - 08:00 21 Mars



View towards south - 16:00 21 Mars



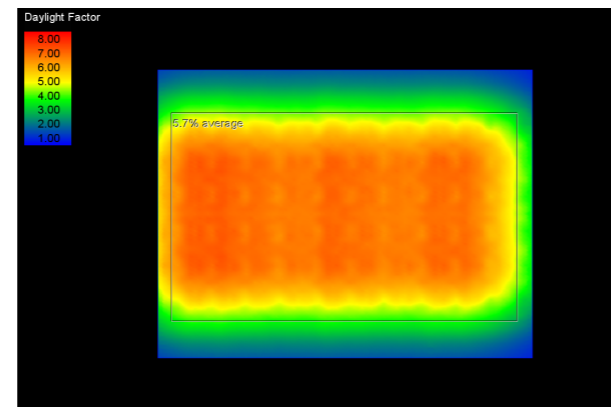
View towards north



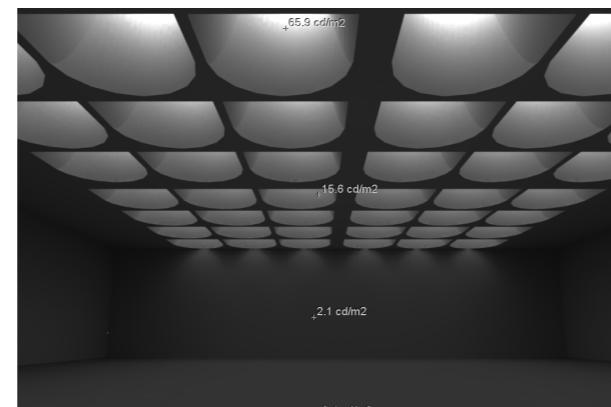
Luminance cd/m²

Skylight study
#1 Flat skylight profile

- Room dimensions: (LxWxH)** 46x35,5x8,5m
- Window dimensions: (LxW)** Skylights: 2.55m²
- Underkant vindu:** Skylights depth - 2.6m
- Glass to Floor Area Ratio (GFAR):** 234/1500 = 15.6%
- Light transmittance:** 68%
- Sky condition** Sunny sky



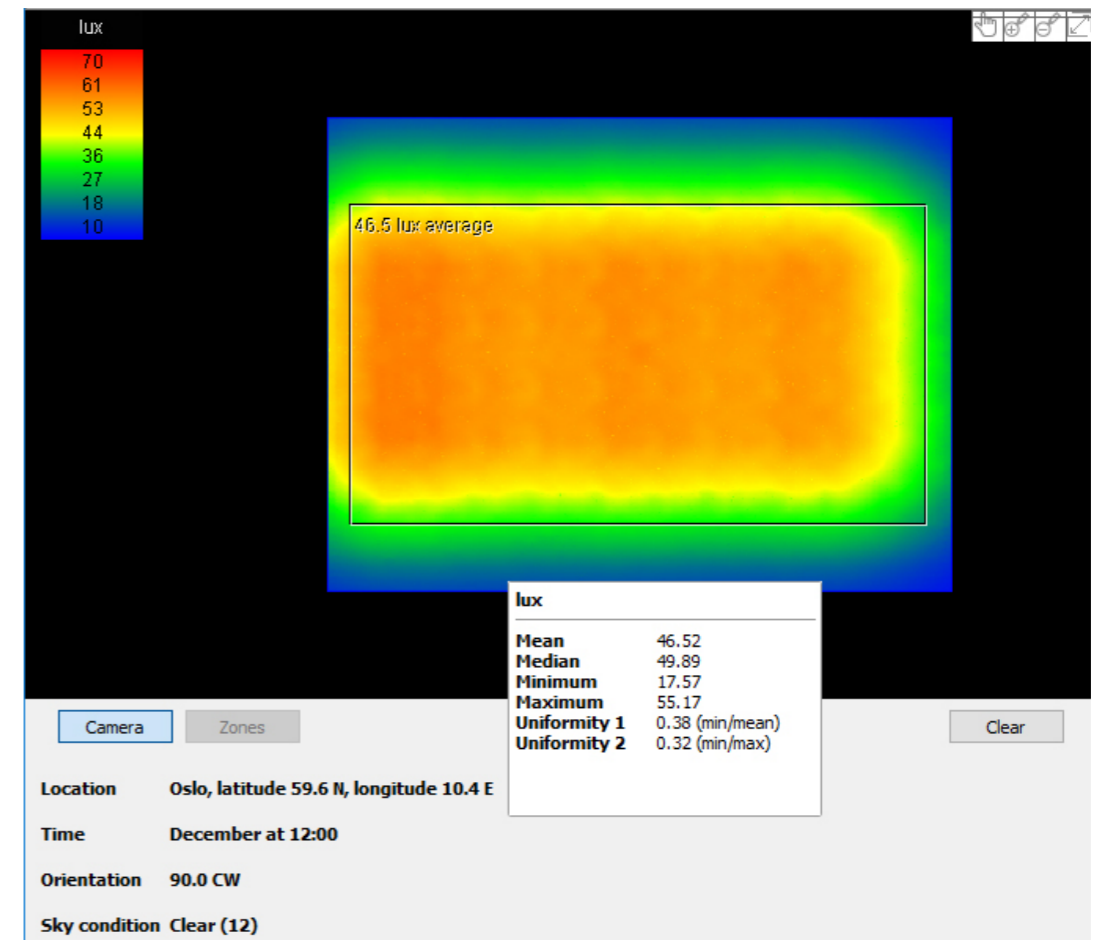
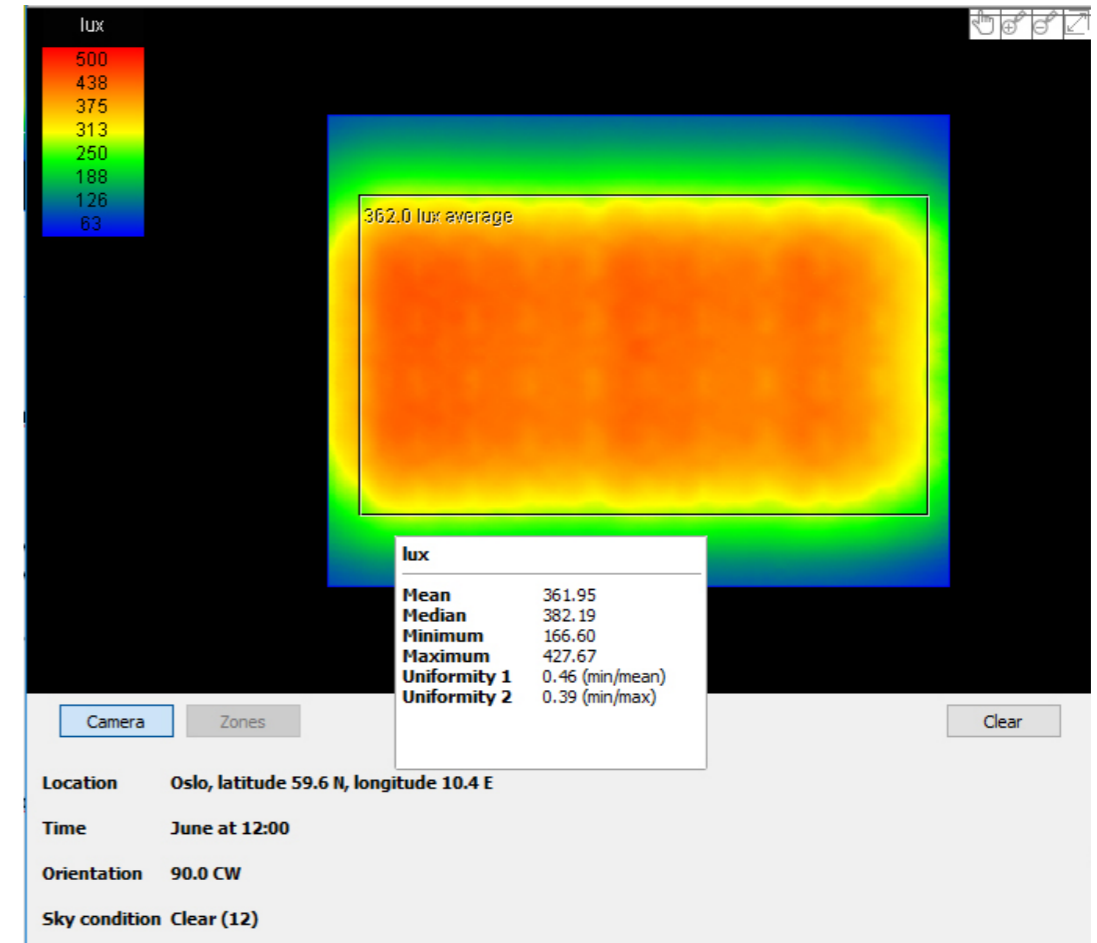
Mean daylight factor: 5.7

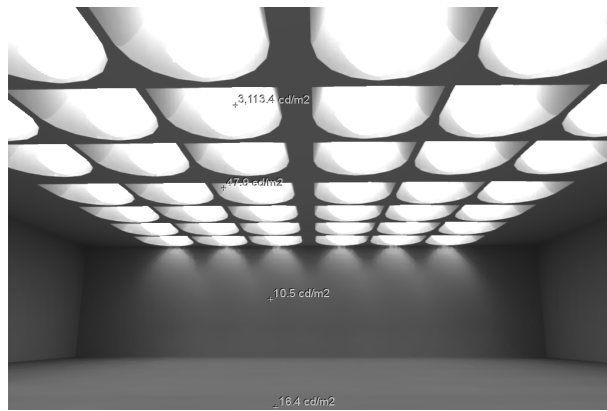
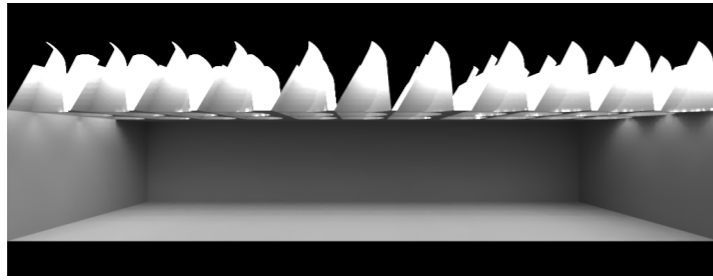


21st of December

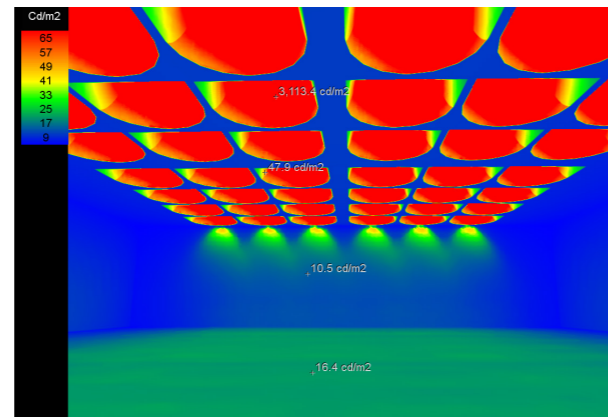
Comments:

A flat skylight is very efficient in regards to daylight factor as it "see" the most of the sky. The shape of the coffer opening restrict the direct sunlight from entering the space.





View towards north

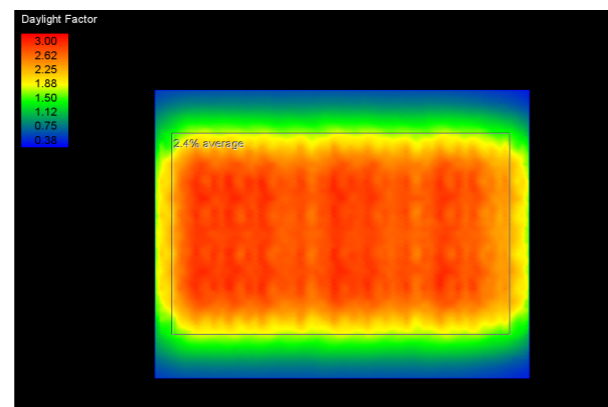


Skylight study
#2 Tilted skylight 63° south

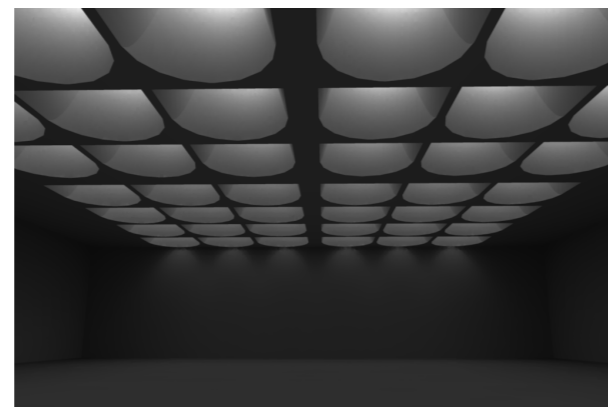
- Room dimensions:** 46x35,5x8,5m
(LxWxH)
- Window dimensions:** Skylights: 3.55m²
(LxW)
- Underkant vindu:** Skylights depth - 2.6m
- Glass to Floor Area Ratio (GFAR):** 234/1500 = 15.6%
- Light transmittance:** 68%
- Sky condition** Sunny sky

Comments:

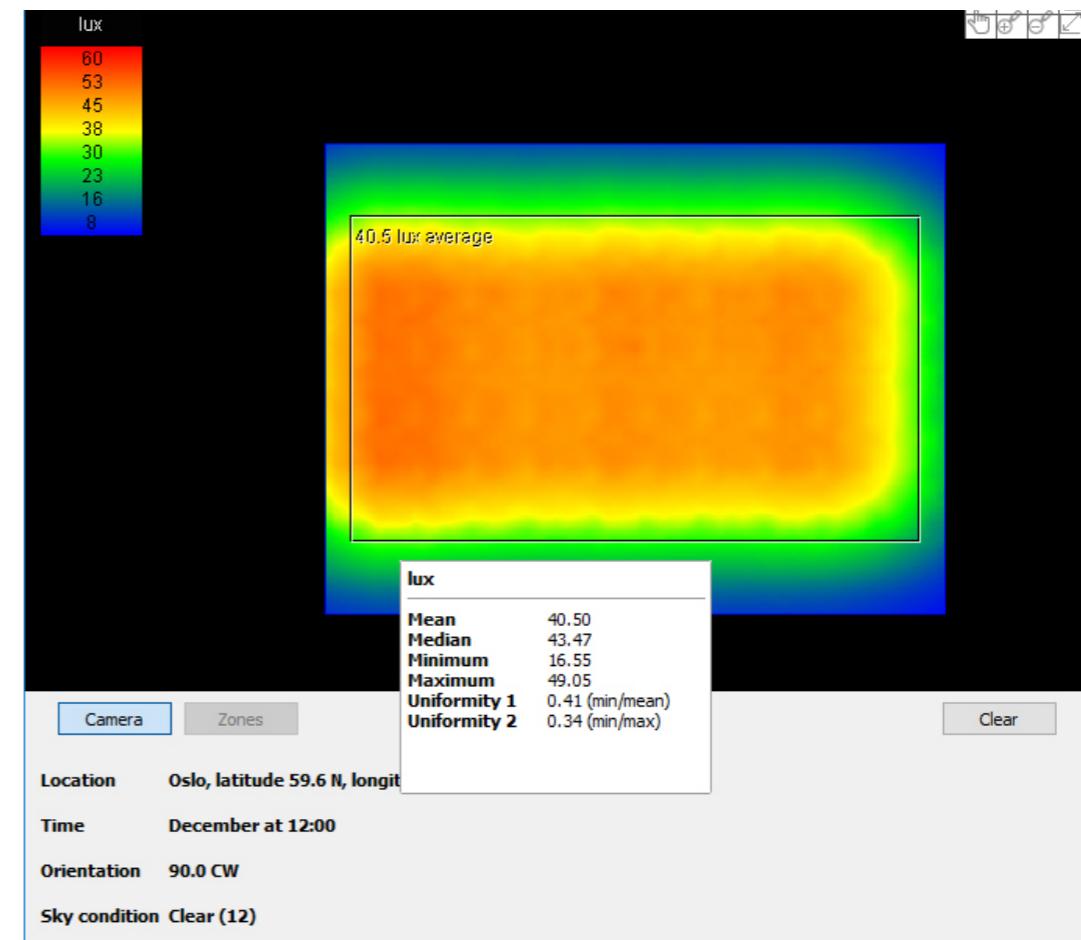
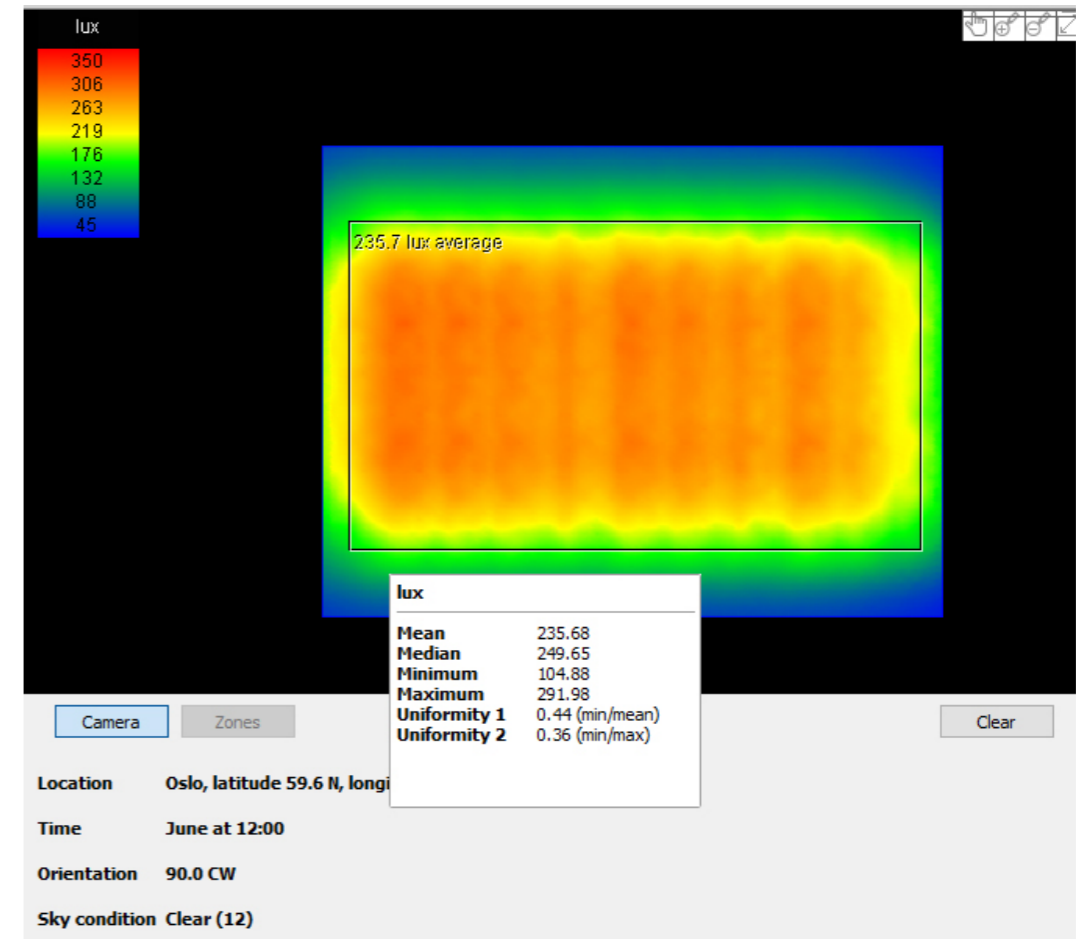
Tilted skylight towards the sun has only got an effect if the spacing between the skylight is sufficient. In this case, as the calculation shows, the skylights shadow each other heavily when tilted.
The daylight factor is rather low.

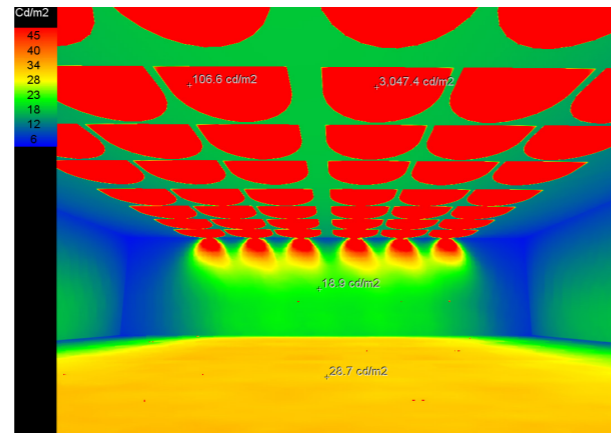
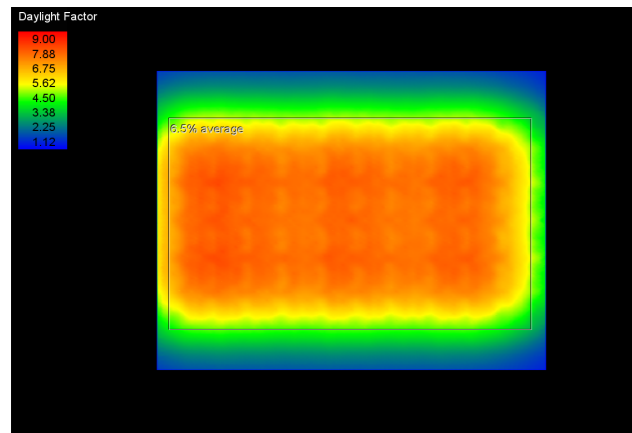


Mean daylight factor: 2.4



21st of December





Comments:

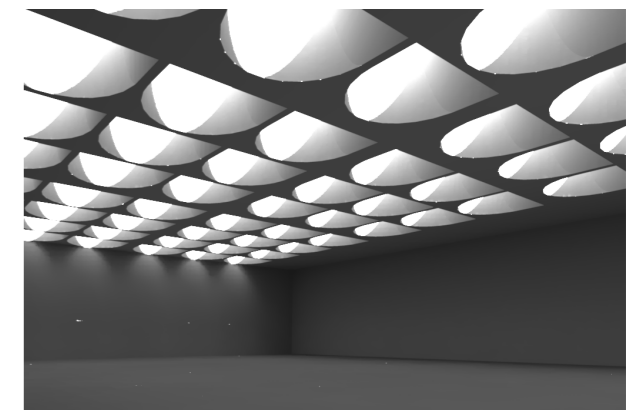
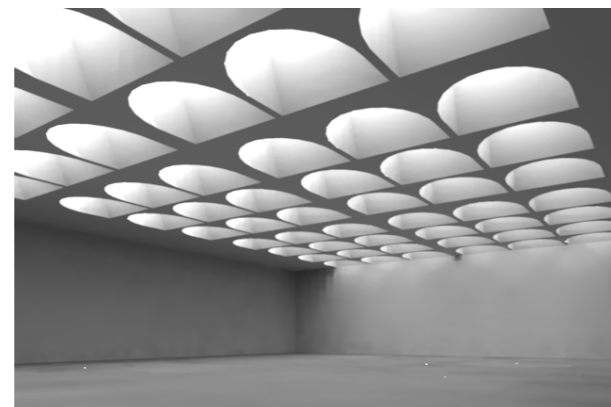
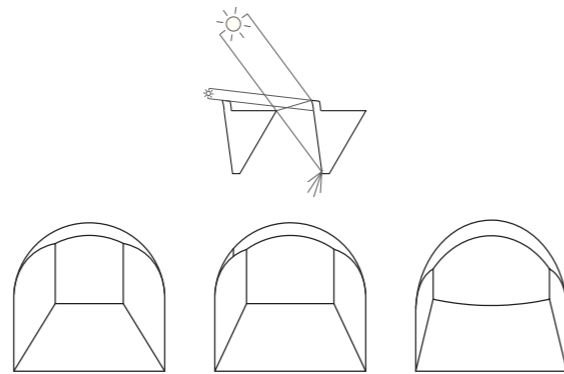
The most optimal skylight version provide a lot of daylight into the space. The glass to floor ratio is very high and windows are likely to have a ventilation mecanism to let out hot air. Needs to be clarified.

The scale and shape of the windows also fragment the roof into elements.

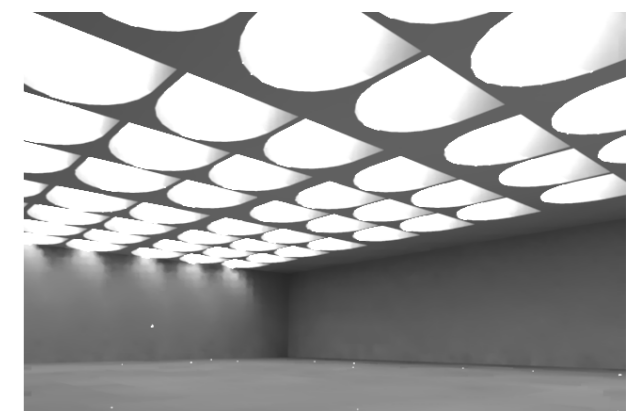
The direct sunlight hitting the inside of the coffers show in theory to be a potential source of glare with a high contrast ratio. Assesment must be made in scale model.

Skylight study
#3 Optimized skylight

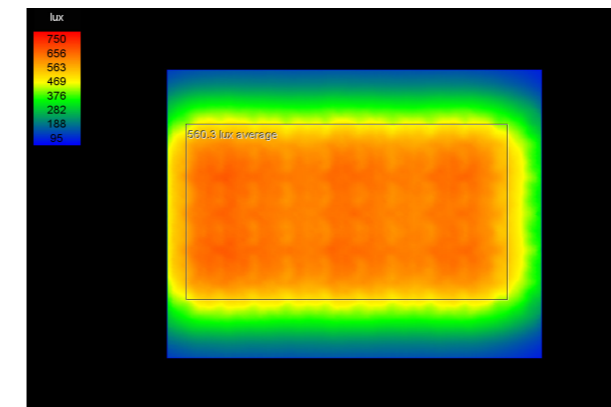
Mean	6.51
Median	6.97
Minimum	2.52
Maximum	7.89
Uniformity 1	0.39 (min/mean)
Uniformity 2	0.32 (min/max)
Room dimensions: (LxWxH)	45x30x7m
Window dimensions: (LxW)	4.26m ²
Underkant vindu:	Skylights depth - 2.6m
Glass to Floor Area Ratio (GFAR):	281/1500 =19%
Light transmittance:	68%
Sky condition	CIE overcast sky



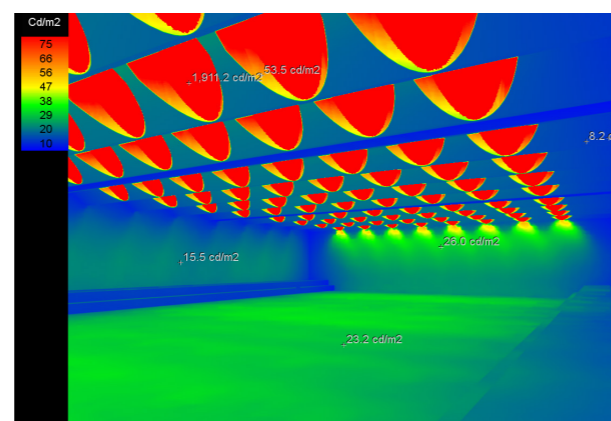
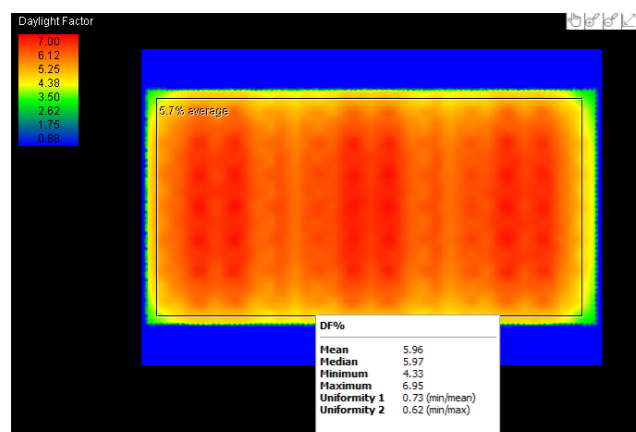
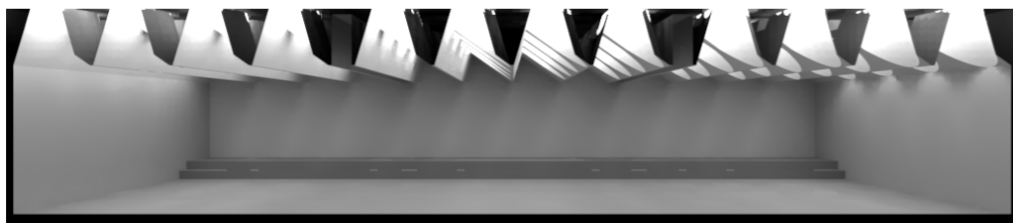
Sun hits inside of coffer - 12:00 21 June



View towards north and south - 12:00 21 June



Skylights can give average illuminance values of 550Lux at 12:00 21 of June and around 50Lux 21 December



Skylight study #4.1
 Skylights integrated as part of the construction - Alternative 1

Mean	5.96
Median	5.97
Minimum	4.33
Maximum	6.95
Uniformity 1	0.73 (min/mean)
Uniformity 2	0.62 (min/max)

Room dimensions: 47x32.3x7m (LxWxH)

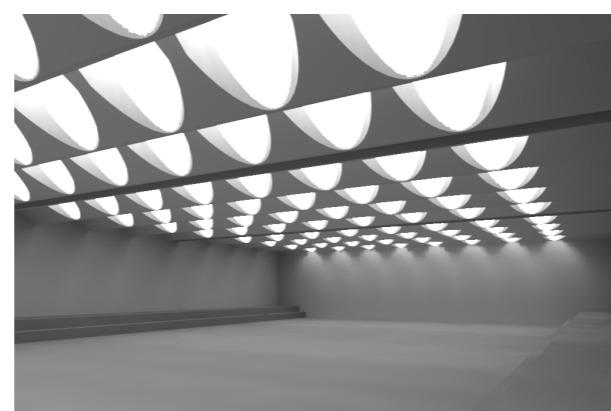
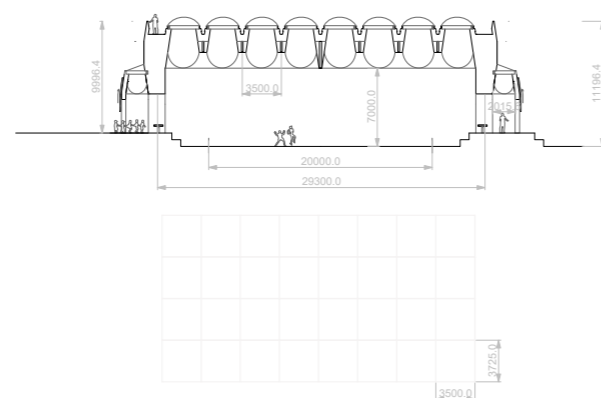
Window dimensions: Skylights: 96x2,72m²= 261m² (LxW)

Underkant vindu: Skylights total depth - 3.5m

Glass to Floor Area Ratio (GFAR): 261/1519 =17.2%

Light transmittance: 68%

Sky condition CIE overcast sky



View towards north - 12:00 21 June

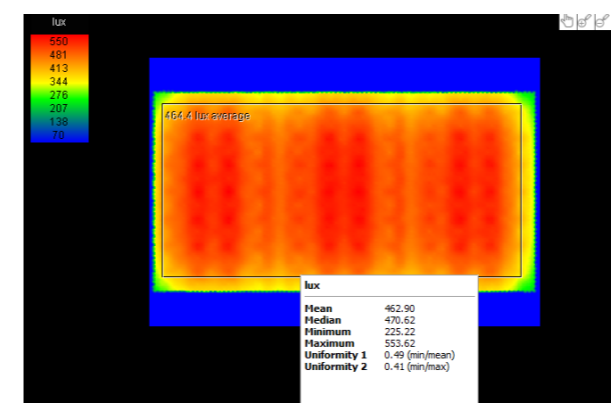
Comments:

Skylights with a rounded north side screens sunlight from entering the floor area in the hall.

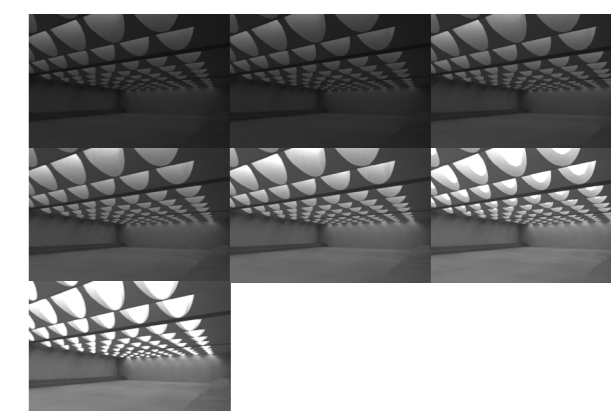
The coffer grid is 3.5x3.73m.

Visually, I prefer that the offer opening are close together in the transversal direction. This further improves uniformity in the light.

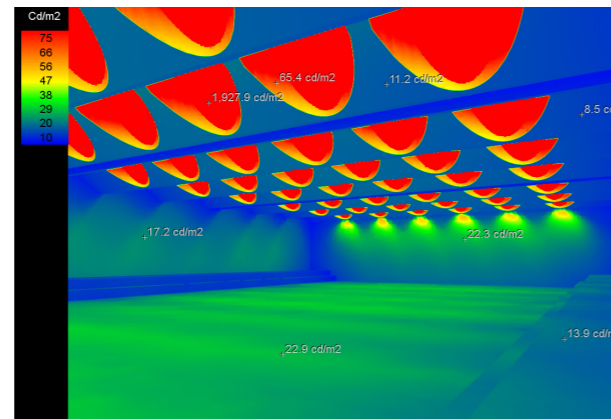
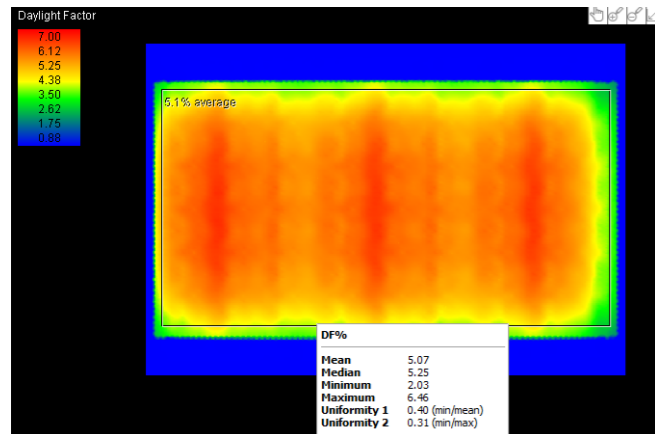
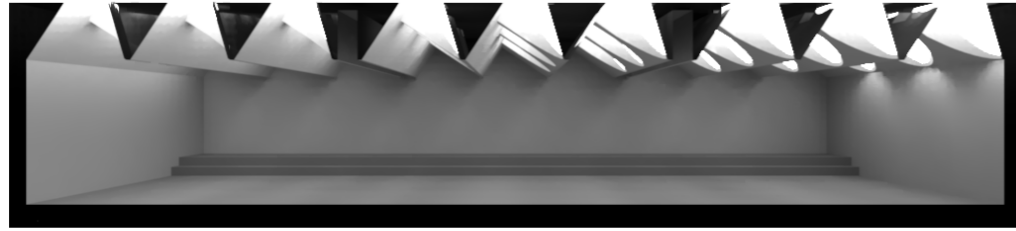
The uniformity values are very good. The illuminance requirements for international matches are 500Lux, 1m above floor, with a uniformity of 0.7. (Idrettshaller planlegging og bygging) The calculations show that this solution has the potential of covering the need for electric light for a large part of the year.



Average of 462 Lux - 12:00 21 June
 Average of 76 Lux - 12:00 21 December



December 21 - June 21 12:00



Comments:

Skylights with a rounded north side screens sunlight from entering the floor area in the hall. The coffer grid is 4.99x4.69m.

Positive:

The scale of both skylights and distance between beams suits the scale of the space. Fewer skylights.

Negative:

The uniformity values are not as good as with alternative 1. Illuminance levels and daylight factor are also a little lower.

Skylight study #4.2
Skylights integrated as part of the construction - Alternative 2

Mean	5.07
Median	5.25
Minimum	2.03
Maximum	6.46
Uniformity 1	0.40 (min/mean)
Uniformity 2	0.31 (min/max)

Room dimensions: (LxWxH) 47x32.3x7m

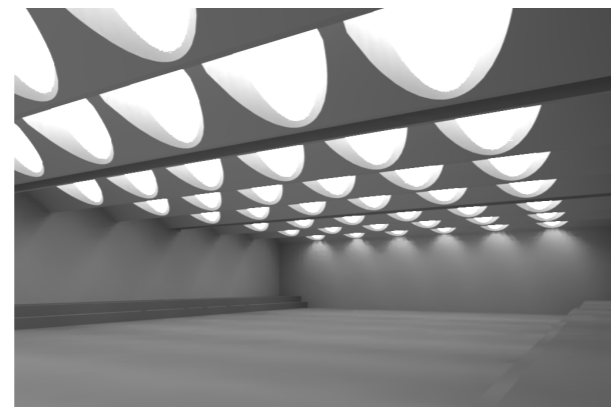
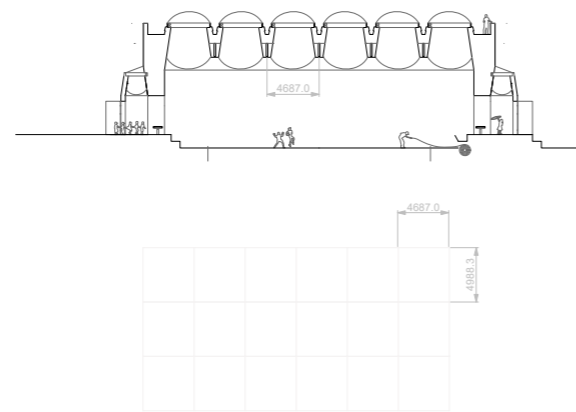
Window dimensions: (LxW) Skylights: 63x3,48m²= 219m²

Underkant vindu: Skylights total depth - 3.5m

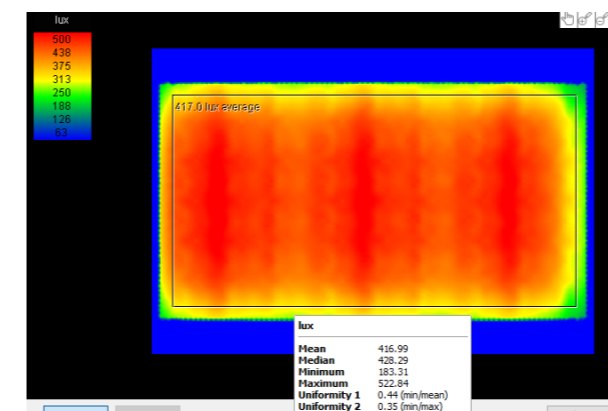
Glass to Floor Area Ratio (GFAR): 219/1519 =14.4%

Light transmittance: 68%

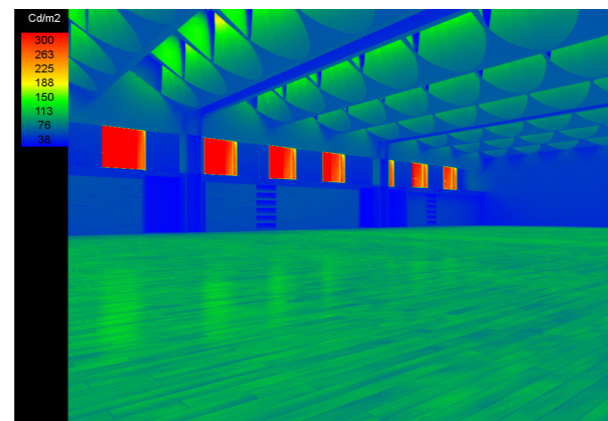
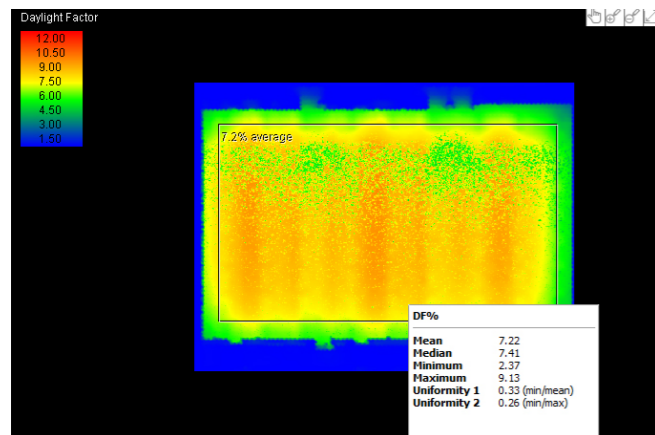
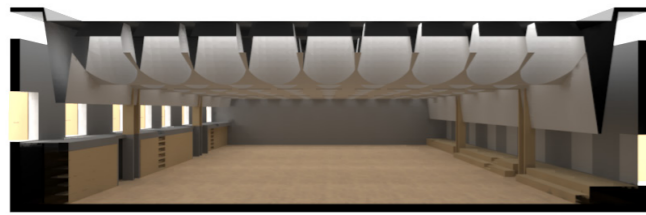
Sky condition CIE overcast sky



View towards north - 12:00 21 June



Average of 417 Lux - 12:00 21 June
Average of 69 Lux - 12:00 21 December



Comments:

The skylight solution can function as a main lightsource for the hall in a large portion of the year. 21 of March represents a median.

The uniformity is a bit low compared to requirements of electric lighting. The reason for a low uniformity is a larger axis distance between beams than earlier example that had better uniformity.

Skylight study
 Skylights integrated as part of the construction -
 Final version

Mean	7.22
Median	7.41
Minimum	2.37
Maximum	9.13
Uniformity 1	0.33 (min/mean)
Uniformity 2	0.26 (min/max)

Room dimensions: 47x35.5x7m
 (LxWxH)

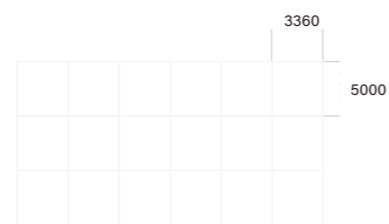
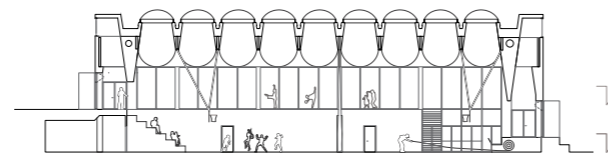
Window dimensions: Skylights: 63x3,48m²= 219m²
 (LxW)

Underkant vindu: Skylights total depth - 3.5m

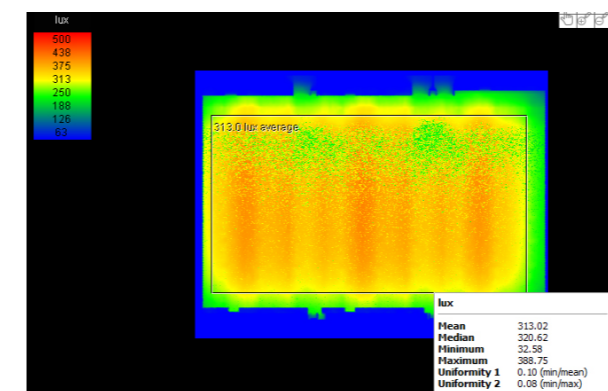
Glass to Floor Area Ratio (GFAR): Skylights 243/1650 =14.1%

Light transmittance: 68%

Sky condition CIE overcast sky



View towards north - 12:00 21 March



Average of 313 Lux - 12:00 21st of March