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 March 21st - 12:00
Average of 308 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 May 21st - 12:00
Average of 478 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

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

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
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

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 in Falkonergården.

Falkonergården is a smaller hall size measuring 28x18m. Some direct sunlight fall into the hall space.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Mean</td>
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<td>Maximum</td>
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<tr>
<td>Uniformity 1</td>
<td>0.3 (min/mean)</td>
</tr>
<tr>
<td>Uniformity 2</td>
<td>0.25 (min/max)</td>
</tr>
<tr>
<td>Room dimensions: (LxWxH)</td>
<td>45x25x9m</td>
</tr>
<tr>
<td>Window dimensions: (LxW)</td>
<td>3x3m (coffer opening)</td>
</tr>
<tr>
<td>Underkant vindu:</td>
<td>Skylights depth - 2.8m</td>
</tr>
<tr>
<td>Glass to Floor Area Ratio (GFAR):</td>
<td>30.5%</td>
</tr>
<tr>
<td>Light transmittance:</td>
<td>60% Opaque glass</td>
</tr>
<tr>
<td>Sky condition</td>
<td>CIE overcast sky</td>
</tr>
</tbody>
</table>
### DF% - Toplit room
#### School in Claus - Dietrich architecten

<table>
<thead>
<tr>
<th>Mean</th>
<th>Median</th>
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<th>Maximum</th>
<th>Uniformity 1</th>
<th>Uniformity 2</th>
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<td>4.56</td>
<td>0.39 (min/mean)</td>
<td>0.31 (min/max)</td>
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</tbody>
</table>

**Room dimensions:** 27x29x7m

**Window dimensions:** 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

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### DF% - Toplit room
#### Lenbachhaus Museum - Fosters architects

<table>
<thead>
<tr>
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<th>Uniformity 1</th>
<th>Uniformity 2</th>
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<td>2.46</td>
<td>0.45 (min/mean)</td>
<td>0.35 (min/max)</td>
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</tbody>
</table>

**Room dimensions:** 45x25x9m

**Window dimensions:** 1x25m

**Underkant vindu:** Skylights depth - 2.9m

**Glass to Floor Area Ratio (GFAR):** 42.2%

**Light transmittance:** 68%

**Sky condition:** CIE overcast sky

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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

<p>| | |</p>
<table>
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<tbody>
<tr>
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<td>Maximum</td>
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<td>0.37 (min/mean)</td>
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<tr>
<td>Uniformity 2</td>
<td>0.29 (min/max)</td>
</tr>
</tbody>
</table>

**Room dimensions:** 45x30x7m

**Window dimensions:**
- Skylights: 77x144m² = 110.9m²
- Sun scoops: 2x37x3.6m + 2x(21.7x3.6m) = 422m²

**Underkant vindu:** Skylights depth - 2.6m

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

**Light transmittance:** 68%

**Sky condition:** CIE overcast sky

**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.
Skylight study

#1 Flat skylight profile

Room dimensions: 46x35,5x8,5m

Window dimensions: 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

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.

21st of December
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

Mean daylight factor: 2.4

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.
### Skylight Study

#### #3 Optimized skylight

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<td>0.39 (min/mean)</td>
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<tr>
<td>Uniformity 2</td>
<td>0.32 (min/max)</td>
</tr>
</tbody>
</table>

#### Room dimensions:

(LxWxH) 45x30x7m

#### Window dimensions:

(LxW) 4.26m²

#### Underkant vindu:

Skylights depth - 2.6m

#### Glass to Floor Area Ratio (GFAR):

281/1500 =19%

#### Light transmittance:

68%

#### Sky condition:

CIE overcast sky

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**Comments:**

The most optimal skylight version provides a lot of daylight into the space. The glass to floor ratio is very high and windows are likely to have a ventilation mechanism 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. Assessment must be made in scale model.

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**Sky condition:**

CIE overcast sky

**Light transmittance:**

68%

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

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**View towards north and south - 12:00 21 June**

**Sun hits inside of coffer - 12:00 21 June**

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**Rectangular shaped light opening**

1.2x1.2m

Glass area 1.44m²

Coffer opening 3.05m

Coffer angle 7.69°/30.24°

**Sculptural coffer variation #2**

**Sculptural coffer variation #3**

**A square aperture does not use the full potential of the ceiling depth to cut off direct sunlight due to the square diagonal corners between coffer opening and aperture opening. A disadvantage may be that the first monitor quickly will shadow the next. By rounding the north edge of the coffer opening and keeping with the previous angles, both the aperture and coffer opening can be increased. A rounded opening is easier to center and the coffer opening can be increased.**

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**Winter solstice**

Oslo 59.9°

Sun altitude 6.6°

**Summer solstice**

Oslo 59.9°

Sun altitude 53.38°

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**Ref:** William Lam - Sunlight as formgiver for architecture, p.144.

(Temperature Boston 42°)

Tilted roof towards south improves winter/summer performance ratio.

"45 degree slope Improves winter /summer ratio (of light to heat admitted) from 5:1 to 2:1 With a 60 degree slope, illumination at noon in summer and winter would be equal."
Skylight study #4.1
Skylights integrated as part of the construction - Alternative 1

<table>
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<tr>
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<td>0.73 (min/mean)</td>
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<td>Uniformity 2</td>
<td>0.62 (min/max)</td>
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</table>

Room dimensions: 47x32.3x7m

Window dimensions: Skylights: 96x2.72m² = 261m²

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

**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 500 Lux, 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

View towards north - 12:00 21 June

December 21 - June 21 12:00
Skylight study #4.2
Skylights integrated as part of the construction - Alternative 2

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<td>Maximum</td>
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<td>Uniformity 1</td>
<td>0.40 (min/mean)</td>
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<tr>
<td>Uniformity 2</td>
<td>0.31 (min/max)</td>
<td>0.31 (min/max)</td>
</tr>
</tbody>
</table>

Room dimensions: 47x32.3x7m

Window dimensions: 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

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
Skylights integrated as part of the construction - Final version

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<table>
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<td>Uniformity 2</td>
<td>0.26 (min/max)</td>
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</table>

Room dimensions: 47x35.5x7m

Window dimensions: Skylights: 63x3,48m² = 219m²

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

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.