High Performance Roof Daylighting
The Passive House standard is part of the solution.
Why Daylighting?

- We are all more healthy and productive
  - We all sleep better at night
  - Increase productivity
  - Students perform better
  - Stores sell more products
Why Daylighting?

Aesthetics

Kimball Art Museum, Louis Kahn
Other Benefits?

Natural Ventilation

Exterior Access

Energy Positive Potential
Extend Benefits Deep To Interior

IECC daylight requirement on top floor (C402.4.2)

Johnson Wax Administration Building, Frank Lloyd Wright
• Windows mostly provide indirect daylight from the sky
• Skylights can combine direct sunlight in addition to diffuse daylight
• Skylights can easily be 3-10 times smaller than a window to collect the same amount of light

Direct Sun
5,000 – 10,000 fc

Bright, sunlit clouds
3,000 – 5,000 fc

Blue Sky
1,000 – 3,000 fc

Dark, heavy clouds
1,000 fc

fc = foot candles – a measure of illumination from a light source
Challenges for roof daylighting?

- Glare
- Winter heat losses
- Summer over-heating
- Condensation
Comfort Drivers

- Even light distribution
- Uniform surface temperatures

Aaron Leitz Photography
Energy Balance

Building Footprint: 200ft x 200ft
Skylights: 36 (38”x38” each)
Total glass area: 323 SF
Thermal Values

Unsere Ingenieure übernehmen für Sie die Berechnung:

\[ U_W = U_g \times A_g + \sum (U_f \times A_f) + \sum \psi \times l_i + \chi \times A_g + \sum A_f \]

- \( U_W \): Wärmedurchgangswert des gesamten Lichtbandes ohne Zarge
- \( A_W \): gesamte wärmeabstrahlende Fläche des Lichtbandes
  \( A_W = A_g + \sum A_f \)
- \( U_g \): Wärmedurchgangskoeffizient der Verglasung in horizontaler Einbaurlage
- \( A_g \): Flächenanteil der Verglasung
- \( U_f \): Wärmedurchgangskoeffizient der Rahmenbauteile
- \( A_f \): Flächenanteil der Rahmenprofile
- \( \psi \): längenbezogener Wärmebrückenverlustkoeffizient
- \( \chi \): punktförmiger Wärmebrückenverlustkoeffizient
  (Wird für Klappen und Lastkonverter angesetzt)

Nur unter dieser Betrachtung ist ersichtlich, wie sich der Wärmedurchgangskoeffizient der einzelnen Bauteile direkt auf die Energiebilanz eines Gebäudes auswirkt.
Thermally optimized

NEW: “warm edge” with Super Spacer in serial-production triple glazing

NEW: optimised impermeable core

NEW: triple layered seal system

Upstand with layered geometry to hold layered seal
Thermal Values

Unit Skylights with insulated curbs

Installed skylight U-value: 0.15 (R-7)

Glass U-value: 0.11 (vert) = 0.13 (hor)
Frame U-value: 0.11
Spacer psi value: 0.017
Light Transmission / SHGC

Light transmission to Solar Heat gain coefficient ratio
- Sunglasses (bronze tint) between 1 and 1.2
- Better 2
- Maximum theoretically possible 2.5

Optimize diffuse daylight - high VT with orientation and shading devices

Einkaufcenter Rhein-Galerie, Ludwigshafen
## Energy Balance (heating)

**Building Footprint:** 200ft x 200ft  
**Skylights:** 36 (38”x38” each)  
**Total glass area:** 323 SF

<table>
<thead>
<tr>
<th>Skylight</th>
<th>Thermal Bridge Free</th>
<th>Curb Insulation</th>
<th>Uglass BTU/hr.ft²°F</th>
<th>SHGC</th>
<th>Losses kBTU/yr</th>
<th>Solar Gains</th>
<th>Total Heat Gain or Loss</th>
<th>Total of heat loss/gain for building (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double pane</td>
<td>No</td>
<td>None</td>
<td>0.24</td>
<td>30%</td>
<td>25935</td>
<td>11687</td>
<td>14248</td>
<td>212748 (7%)</td>
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<tr>
<td>Triple pane - conventional spacer</td>
<td>No</td>
<td>Non-Continuous</td>
<td>0.18</td>
<td>30%</td>
<td>23907</td>
<td>11053</td>
<td>12854</td>
<td>210114 (6%)</td>
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<tr>
<td>Triple pane - better spacer</td>
<td>Yes</td>
<td>Non-Continuous</td>
<td>0.18</td>
<td>30%</td>
<td>21907</td>
<td>11053</td>
<td>10854</td>
<td>208898 (5%)</td>
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<tr>
<td>Advanced component – low SHGC</td>
<td>Yes</td>
<td>4” Continuous</td>
<td>0.13</td>
<td>30%</td>
<td>10835</td>
<td>11032</td>
<td>-197</td>
<td>198079 (0%)</td>
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<tr>
<td>Advanced component – high SHGC</td>
<td>Yes</td>
<td>4” Continuous</td>
<td>0.13</td>
<td>50%</td>
<td>10835</td>
<td>18332</td>
<td>-7497</td>
<td>198079 (-4%)</td>
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<tr>
<td>Advanced component – high SHGC, shaded in summer</td>
<td>Yes</td>
<td>4” Continuous</td>
<td>0.13</td>
<td>50%</td>
<td>10835</td>
<td>18387</td>
<td>-7552</td>
<td>191389 (-4%)</td>
</tr>
</tbody>
</table>

Total reduction of heat demand of **21359 kBTU/yr** – **11% improvement** (excluding lighting energy savings)
Energy Balance (cooling)

Building Footprint: 200ft x 200ft  
Skylights: 36 (38”x38” each)  
Total glass area: 323 SF

<table>
<thead>
<tr>
<th>Skylight</th>
<th>Thermal Bridge Free</th>
<th>Curb Insulation</th>
<th>R-skylight installed</th>
<th>Area</th>
<th>Cooling Gt F*day/yr</th>
<th>Summer heat Gains kBTU/sf*yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double pane</td>
<td>No</td>
<td>None</td>
<td>0.24</td>
<td>400</td>
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<td>14111</td>
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<tr>
<td>Triple pane - conventional spacer</td>
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<td>Non-Continuous</td>
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<td>11994</td>
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<td>4&quot; Continuous</td>
<td>0.13</td>
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<td>5988</td>
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<tr>
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<td>4&quot; Continuous</td>
<td>0.13</td>
<td>400</td>
<td>2863</td>
<td>5988</td>
</tr>
<tr>
<td>Advanced component – high SHGC, shaded in summer</td>
<td>Yes</td>
<td>4&quot; Continuous</td>
<td>0.13</td>
<td>400</td>
<td>2863</td>
<td>5988</td>
</tr>
</tbody>
</table>

Total reduction of heat gain by transmission – **8123** kBTU/yr (Reduction of **57%**)
# Energy Balance (cooling)

**Building Footprint:** 200ft x 200ft  
**Skylights:** 36 (38”x38” each)  
**Total glass area:** 323 SF

<table>
<thead>
<tr>
<th>Skylight</th>
<th>Thermal Bridge Free</th>
<th>Curb Insulation</th>
<th>U_{glass} BTU/hr.ft²°F</th>
<th>SHGC</th>
<th>Summer solar Gains kBTU/sf*yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double pane</td>
<td>No</td>
<td>None</td>
<td>0.24</td>
<td>30%</td>
<td>28364</td>
</tr>
<tr>
<td>Triple pane - conventional spacer</td>
<td>No</td>
<td>Non-Continuous</td>
<td>0.18</td>
<td>30%</td>
<td>28364</td>
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<tr>
<td>Triple pane - better spacer</td>
<td>Yes</td>
<td>Non-Continuous</td>
<td>0.18</td>
<td>30%</td>
<td>28364</td>
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<tr>
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<td>0.13</td>
<td>30%</td>
<td>28311</td>
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<td>Yes</td>
<td>4” Continuous</td>
<td>0.13</td>
<td>50%</td>
<td>47185</td>
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<tr>
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<td>4” Continuous</td>
<td>0.13</td>
<td>50%</td>
<td>18874</td>
</tr>
</tbody>
</table>

Total reduction of cooling load by shading 50% SHGC compared to 30% SHGC glass – app 10,000 kBTU/yr (-33%)
Condensation

1 **Durable Aluminum Cap:** Baked brown enamel finish*

2 **Installation:** Outside fastening as standard. Inside fastening also available.

3 **Base Frame:**
   - a Thermally broken white PVC base frame
   - b Thermally broken aluminum base frame

4 **Condensation channel:** 4 sided channel with weep holes in each corner

5 **Curb:**
   - a Can be installed on a 2 x 4, 2 x 6 or 2 x 8 curb
   - b Can be installed on a 2 x 4, 2 x 6 or 2 x 8 curb - Requires a full 2” wide curb

6 **Glazing:** 7 glass & 6 acrylic or polycarbonate glazing options *(See page 18)*

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Columbia skylights

Airtight?
Condensation

Thermo active design:
Increase surface temperature at critical junction

Surface temperature stays far above ‘dew point’ of 50F/10C (red line)

Offers protection with higher relative humidities (climate dependant)

Completely airtight (class 4)
Advanced Components

Glass Roofs

Certificate
Certified Passive House component for cool, temperate climate, valid until 31.12.2015

Category: Inclined Curtain Wall
Manufacturer: LAMILUX Heinrich Strunz GmbH
95111 Rehau, GERMANY
Product name: CI-System Glasarchitektur PRIAenergy® (Inclined)

The following comfort criteria were used in awarding this certificate:

Given a Ugs value of 0.72 W/(m²K) by 45° inclination and an element size of 1.20 m by 2.50 m,

\[ U_{CWI} = 0.81 \text{ W/(m²K)} \leq 1.00 \text{ W/(m²K)} \]

Taking into account the installation based thermal bridges, and provided that the installation is, with regard to the thermal bridges, equal or better than shown in the data sheet, the facade meets the following criterion.

\[ U_{CWI,installed} \leq 1.00 \text{ W/(m²K)} \]

Thermal data of the construction

<table>
<thead>
<tr>
<th>Component</th>
<th>U-value (W/(m²K))</th>
<th>Width (mm)</th>
<th>( \Psi_g ) (W/(m²K))</th>
<th>( f_{result} ) (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transom (t)</td>
<td>0.79</td>
<td>60</td>
<td>0.034</td>
<td>0.79</td>
</tr>
<tr>
<td>Mullion (m)</td>
<td>0.79</td>
<td>60</td>
<td>0.034</td>
<td>0.79</td>
</tr>
<tr>
<td>Thermal glass carrier bridge</td>
<td>0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Spacers of lower thermal quality, especially those made of aluminium, lead to significantly higher thermal losses and lower temperature factors.

Further information see data sheet

www.passivehouse.com

Data Sheet
LAMILUX CI-System Glasarchitektur PRIAenergy® (inclined)

Manufacturer: LAMILUX Heinrich Strunz GmbH
95111 Rehau, GERMANY
Tel.: +49 (0) 9283 595 0
www.lamilux.com

Description
Aluminium construction, Aluminium pressure strip; PE-low insulator in the glazing rebate, plastic glass carrier on stainless steel bolts. Used pane: 52 mm (9/15/15/9), intersection of the Glasse: 10 mm. Used spacer: SuperSp. Ti-foil PU.

Thermal data

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* Spacers of lower thermal quality leading to higher thermal losses and lower temperatures.

www.passivehouse.com
Advanced Components

Glass Roofs
Detailing of a glass roof

1. Sealed horizontal mullon-cover joint
2. Self adhering stainless steel cover plate for traverse gasket joint
3. Vertical mullon
4. Exterior vert. mullon gasket
5. Exterior hor. mullon gasket
6. Flashing
7. Horizontal mullon
8. Glass
9. Stainless steel screw connection with epdm seal
Big Design Strategies

- Orientation
- Spacing
- Diffuse the Light
- Ventilation
- Renewables (BIPV)
- Controls/BMS
Orientation

- Daylight from windows limited
- Lightshelf can increase penetration
- Unit skylights with splayed light wells provide the most uniform light
• The general rule of thumb is to space skylights at 1.0 to 1.5 times the ceiling height (center-to-center in both directions)
• Actual designs can vary considerably based upon:
  • Skylight type
  • Light well depth and splay
  • Furniture or shelves
Diffuse the Light

- External shading
- Internal treatments
Glare/solar control

Glass Roofs - shading
Ventilation Integration

In shoulder seasons (night time cooling)

Also for heat / smoke venting
Find out more...
floris@foursevenfive.com
twitter: @475floris