High Performance Glass for High Performance Buildings
C. Barry Pilkington NA Inc.
Zero Energy?

Net Zero Energy?

EU 2002 EPBD: 20/20/20
20% reduction in CO2 and energy, 20% energy from renewables

EU 2010 EPBD
“Nearly zero energy by 2020 for all new buildings”

Zero Carbon Emissions?
Which 2 of the 3 “E”s?

- Excellence
- Economy
- Ease
On-Line Calculators

- Wind Load Capacity
- Thermal Stress
- Single and Insulating Glass Properties (U-Factor, SHGC, Reflection, Color, Tdw, etc.)
- Sound Control
- Energy, Comfort, Daylighting and Glare
### Sun Management Calculator


<table>
<thead>
<tr>
<th>Option</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Exterior Glass</td>
<td></td>
</tr>
<tr>
<td>Outboard Thickness</td>
<td></td>
</tr>
<tr>
<td>Glazing (single or double)</td>
<td></td>
</tr>
<tr>
<td>Inboard Lite</td>
<td></td>
</tr>
<tr>
<td>Inboard Thickness</td>
<td></td>
</tr>
<tr>
<td>Calculate Results</td>
<td></td>
</tr>
</tbody>
</table>

The appearance can be gained with Optifloat™ Clear with optional coatings of Pilkington Activ™ and Pilkington Energy Advantage™.
Spectrum
Thermal Stress Calculator

http://www.pilkingtoncalculators.com/tsc.php

The Pilkington Thermal Stress Calculator computes general guidelines as to which glass combinations and glazing details may demand heat treatment to prevent thermal stress breakage from direct solar radiation. The program evaluates: Single glazed Pilkington products, and double glazed units with one light of Pilkington manufacture and the other from the LBNL Window 5 library, Version 5.2.17a.

The program gives general guidance; it cannot be expected to give precise
Pilkington Sound Simulator

COMFEN by LBNL
Window 5 by LBNL

![Image of the Window 5 software interface showing a glazing system library with details on glass layers, thickness, and U-factor calculations.](Image)

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Mode</th>
<th>Thick</th>
<th>Tsol</th>
<th>Rsol1</th>
<th>Rsol2</th>
<th>Tvis</th>
<th>Rvis1</th>
<th>Rvis2</th>
<th>Tir</th>
<th>E1</th>
<th>E2</th>
<th>Cond</th>
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<td>0.076</td>
<td>0.037</td>
<td>0.037</td>
<td>0.085</td>
<td>0.040</td>
<td>0.040</td>
<td>0.000</td>
<td>0.840</td>
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<table>
<thead>
<tr>
<th>U-factor</th>
<th>SC</th>
<th>SHGC</th>
<th>Rel. Ht. Gain</th>
<th>Tvis</th>
<th>Keff</th>
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<tbody>
<tr>
<td>W/m²K</td>
<td></td>
<td></td>
<td>W/m²</td>
<td>W/m²K</td>
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</table>
Heat flows from hot to cold

Heat transfers by:
  • Radiation
  • Conduction
  • Convection
3 Ways Heat Flows through a Window

Radiation

Conduction

Convection
4 Radiant Energy Types

- UV: 3%
- Visible: 47%
- Solar IR: 50%
- Far IR:

Incandescent light bulb: <5% visible >95% IR
SHGC (Solar Heat Gain Coefficient)

- SHGC simply measures how much (%) of the sun’s heat, shining on a window, ends up in the room.
  - The bigger the SHGC the more heat flows in (from warm to cool).
- Shading Coefficient (SC) compares SHGC of a new glass to the SHGC of an unspecified 3 mm Clear Glass.

SHGC or “SF” or “G” or “Total Solar Transmission”
Far IR Radiation

Solar IR Absorption

Interior Convection

Exterior Convection
U-Factor

• Thermal Conductivity  \( (\text{Btu/hr.sq.ft.}^\circ\text{F}) \) or \( (\text{W/sq.m.}^\circ\text{C}) \)
  Note: Different calculation methods for North Am. vs Europe

• The bigger the U the more the heat flows (from hot to cold, or from warm to cool)

• A small U-Factor is important, both in Dubai and in Finland, but not so important in Hawaii or Malaysia.

• Note: \( R = 1/U \) But R used by insulation makers is from surface to surface while U for glass is not the same. It is from air to air and includes boundary layer air film insulation.
The Second number you need for Glass

**U-Factor**

U-Factor (or U-Value) measures the rate of heat transfer from warm air side to cool air side. Watts/sq.m.degC
How Much Radiant Heat flows across IG gap (no Low-E)?

39% of total flows by Convection/Conduction (for 39 °C temperature difference)

61% of total flows by Radiation

6 mm Tint / air / 6 mm Clear
Adding Low-E is Important

71% of total flows by Convection/Conduction

Heat transfer by Radiation is reduced to 29% of total when EA Low-E and Argon are added

6 mm Clear / Argon / 6 mm EA Low-E #3
## Importance of adding Low-E for SHGC

<table>
<thead>
<tr>
<th>Configuration</th>
<th>SHGC</th>
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<tbody>
<tr>
<td>Single Glazed 6 mm Super Grey</td>
<td>0.35</td>
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<tr>
<td>Double Glazed</td>
<td></td>
</tr>
<tr>
<td>6 mm Super Grey / air / Clear</td>
<td>0.21</td>
</tr>
<tr>
<td>6 mm Super Grey / air / EA Low-E</td>
<td>0.15</td>
</tr>
<tr>
<td>6 mm Super Grey / argon / EA Low-E</td>
<td>0.14</td>
</tr>
</tbody>
</table>
Available Glasses

- Clear and Low-Iron
- Tint and Spectrally Selective Tint
- Hard Coats and Soft Coats
- Solar Reflection
- Solar Absorption
- Solar Transmitting
- Visibly Reflective or Anti-Reflective
- Self Cleaning
Only Three Numbers are needed, You can see the other properties:

1. **SHGC for Solar Control**
   (Shading Coefficient x 0.87 or 0.86 = SHGC)
   Lower value means less solar heat gained inside the building from sun shining on the window

2. **U-Factor for thermal control**
   (Conversion: 1Btu/hr.sq.ft.°F = 5.68 Watt/sq.m.°K)
   Lower value means less heat flow by conduction from warm to cold

3. **Tdw for fading control from UV and light.**
   From Window 5: [http://windows.lbl.gov/software](http://windows.lbl.gov/software)
   1 to 0. Lower number means less fading
All Low-E Coatings are NOT Equal

There are 3 types of Low-E
(All reflect far IR (infra red) radiation ~10 μm)
(All reduce heat flow by conduction – U-Factor)

1. Transmit near Solar IR (1 to 2 μm )
   (most pyrolytic CVD hard coat Low-E )

2. Reflect near Solar IR
   (most vacuum sputtered soft coat Low-E)

3. Absorb near Solar IR
   (sputtered Low-E on tinted glass and some pyrolytic CVD Low-E)
Which Glass is Best?

Always use Low-E

When cost of heating a building exceeds the cost of cooling it use High SHGC See Canada Nat. Res. study

Most commercial buildings have greater cooling costs so use Low SHGC

Put Low-E on surface #2 if possible for lower SHGC

Put Low-E on surface #3 for slightly higher SHGC
• Watch for Moiré patterns with fine detailed screen print patterns in double glazing
Distortions

- Some distortion in heat treated glass is always visible to naked eye under certain conditions from:
  - Tempering/Toughening/Heat Strengthened
  - Double Glazing
  - Laminating
  - Glazing pressures
IG Distortion? (concave #2?)
IG Distortion? (concave #2?)
Laminated Heat Treated
Heat Treated – Dirt on Rollers
Heat Treated – Roller Wave
Tempering/Toughening Quench Pattern

• Some pattern is always visible to naked eye under certain conditions.
• More visible with: Thicker, higher Transmission coatings in Double Glazing.
• See Technical Bulletin ATS #157
HT Quench Marks in Reflection
HT Quench Marks in Transmission
Examples

Santiago, Chile

IG:
6 mm Solar E #2 surface
Air
6 mm Clear Glass
Chongqing
Xinnian Kaiyue City

Grey 6mm+12air+6mm EA
Chongqing Coal Science Institution

Grey 6mm+12air+6mm EA
Tajikistan 6 mm Gold Eclipse #2 / air / 6 mm Clear Glass
Glare?

View from outside

6 mm SuperGrey / air / 6 mm Clear  8% Visible Transmission

North America (Borders Books)

View from Inside

Toledo, Ohio (Honey Baked Ham)
WHAT TO DO:

Select Glass for: Performance, Appearance, Daylight Transmission, Color, Reflectivity, etc.

Use Double Glazing with Low E for better Solar control (lower SHGC).

Perform full design analysis with COMFEN for: Energy, Daylighting, Comfort and Glare.
Sample Viewer

C/D – Coated glass sample standing vertically on horizontal black material (velvet) with a horizontal sheet of white paper.
Glass surface faces viewer (coating on far side).
Direct sunlight shines through glass, towards sheet of white paper.

A – Reference white paper

B – Transmitted color shows on white paper

C – Exterior reflected color shows in glass

(D – Ignore reflection of transmitted color - Not relevant)
Green transmitted color of pure gold
The 3 “E”s

- Excellence
- Economy
- Ease