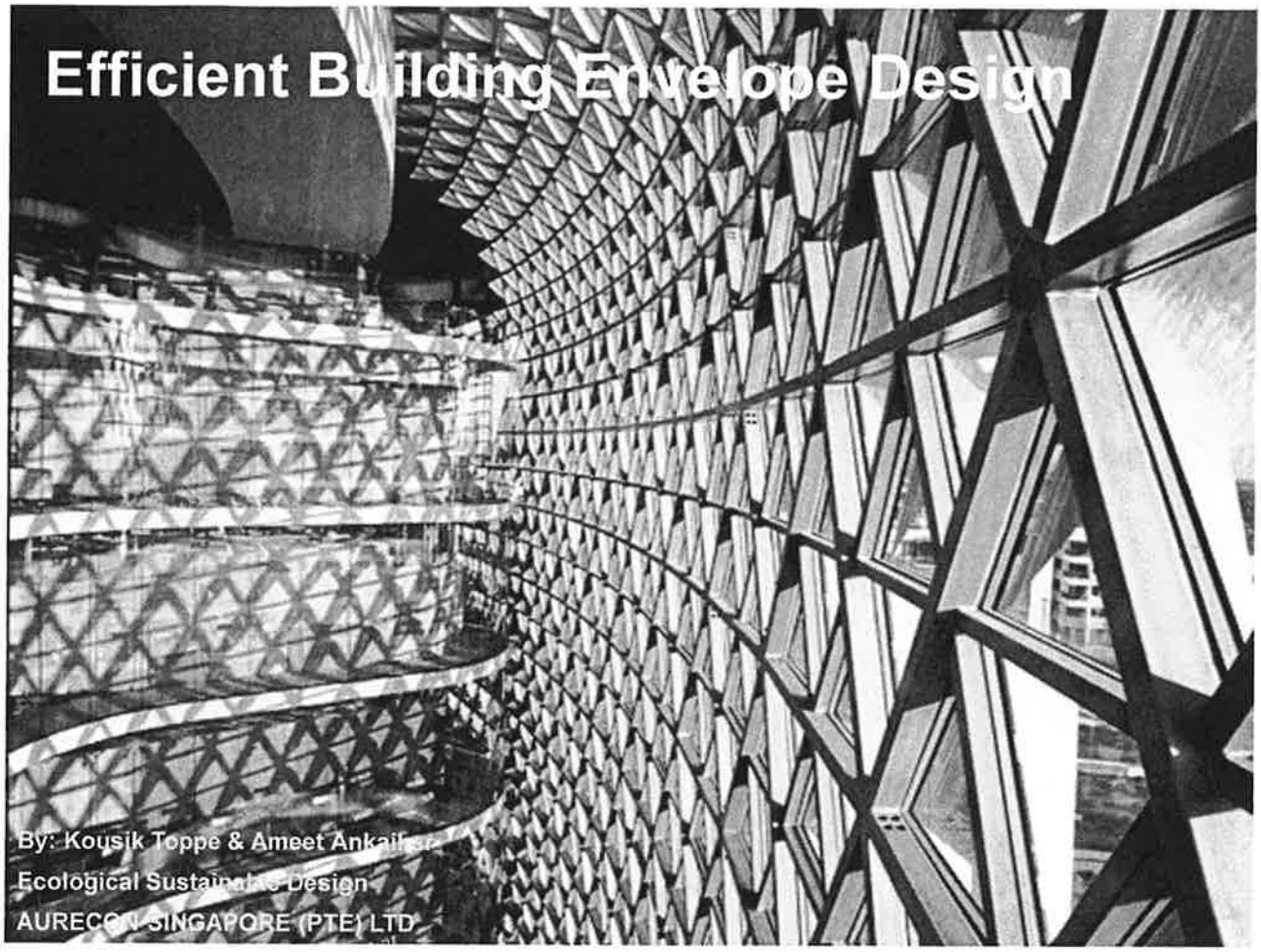
Efficient Building Envelope Design



By: Kousik Toppe & Ameet Ankalkar
Ecological Sustainable Design
AURECON SINGAPORE (PTE) LTD



Content

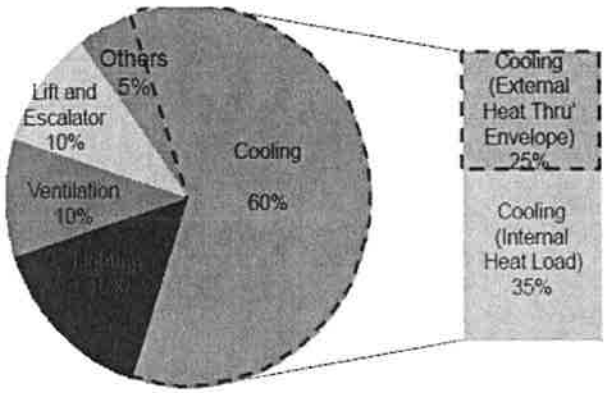
EFFICIENT BUILDING ENVELOPE DESIGN

- Introduction
- ETTV equation and determining elements
- Strategies to lower down ETTV value
- Case Studies
- RETV equation and explanation
- DAYLIGHTING
- Introduction, advantages and disadvantages
- Maximizing daylight in interior
- Minimizing glare and heat from daylight
- OTHER GREEN FEATURES
- Energy saving, water saving and Indoor environmental quality

Meji Dori Shopping Centre Complex, Tokyo, Japan

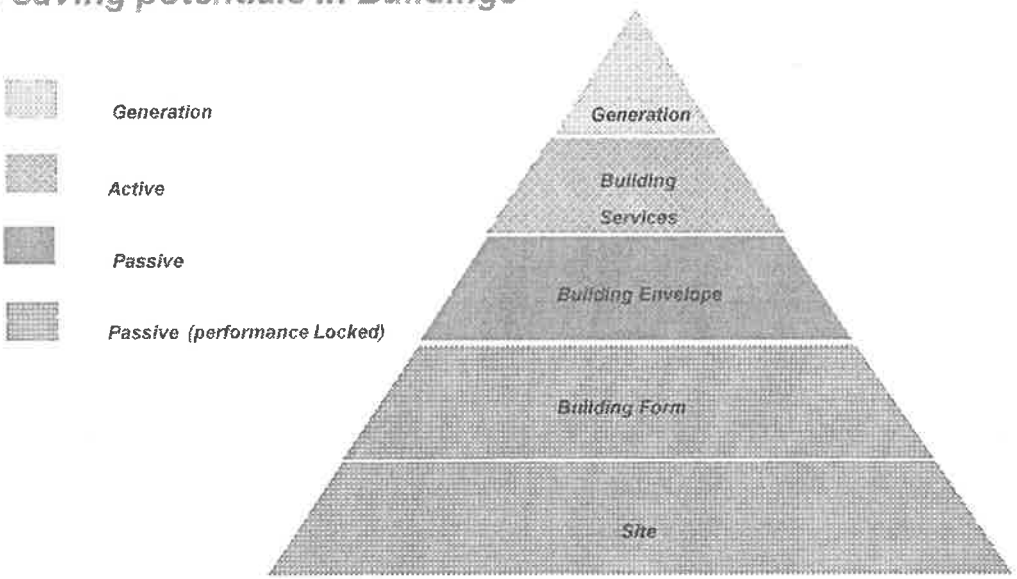
Introduction

- *World wide buildings account for **30 - 40% of Energy consumption***
- *About **70 – 90% of Electricity** is used for Environmental comforts*
- *Buildings have long life cycles and their **impacts are felt for generations***



Introduction

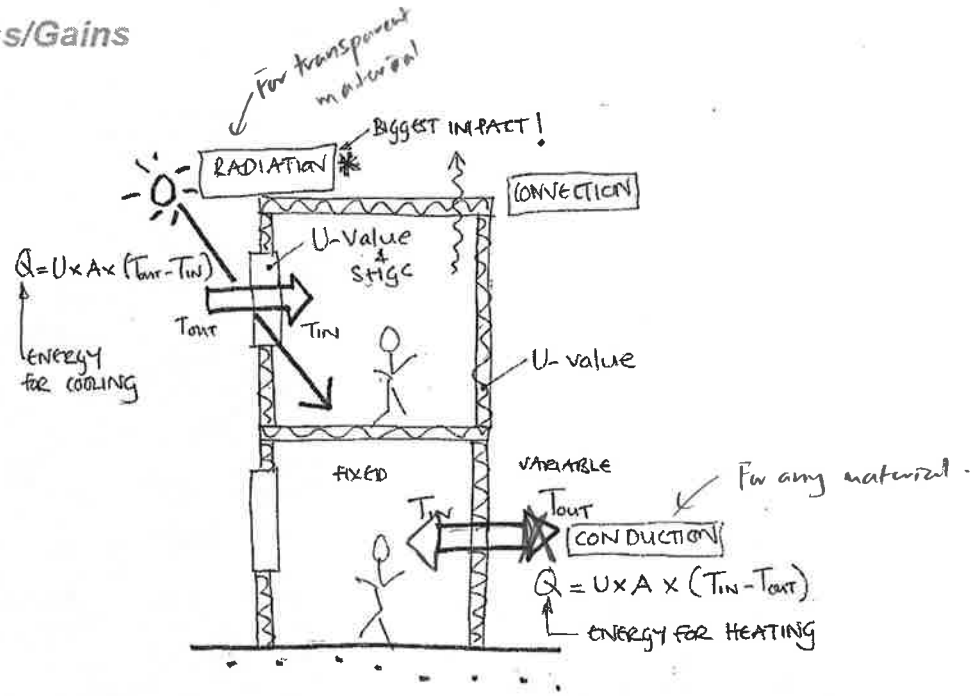
Energy saving potentials in Buildings



The best strategy for energy conservation is the energy not used in the first place

Facade Heat Loss/Gains

- 3 Types:
- Conduction
- Radiation
- Convection



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ETTV - Introduction

- Parameters to control solar heat gain through building envelope:

ETTV → Envelope Thermal Transfer Value (for commercial building)

NRB → use during day time Maximum permissible value is 50 W/m²
outdoor day time temp via indoor day time temp

Assumption

RETV → Residential Envelope Transmittance Value
(for residential building)

RB → use during night time
outdoor night time temp
via indoor night time temp
Maximum permissible value is 25 W/m²



Introduction

Building skin as a responsive skin

Sustainable design considerations

TRANSPARENT VS OPAQUE

National Space Centre Museum, Nicholas Ghrimshaw in Leicester UK

Glass



Float Glass



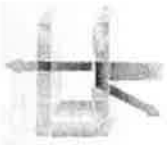
Reflective glass



Bend/Curved glass



Double-glazed glass



Low-emission glass

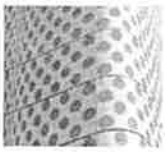


Sand Blasted glass



Fire resistant glass

MATERIALS - Glass



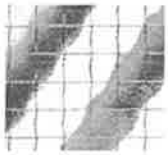
Ceramic Frit Patterns



Tempered Glass



Photo-voltaic Glass



Wired glass



Acid edged glass



Anti-reflective glass

Visit

www.glassonweb.com

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Envelope Thermal Transfer Value

$$ETTV = 12(1-WWR)U_w + 3.4(WWR)U_f + 211\,(WWR)(CF)(SC)$$

Opaque | Transparent

ETTV = Envelope Thermal Transfer Value (W/m^2), max $50W/m^2$

WWR = window-to-wall ratio — total facade area — eg. if 50% of facade is window, WWR = 50% / 100% = 0.5

Uw = thermal transmittance of opaque wall ($W/m^2\,K$)

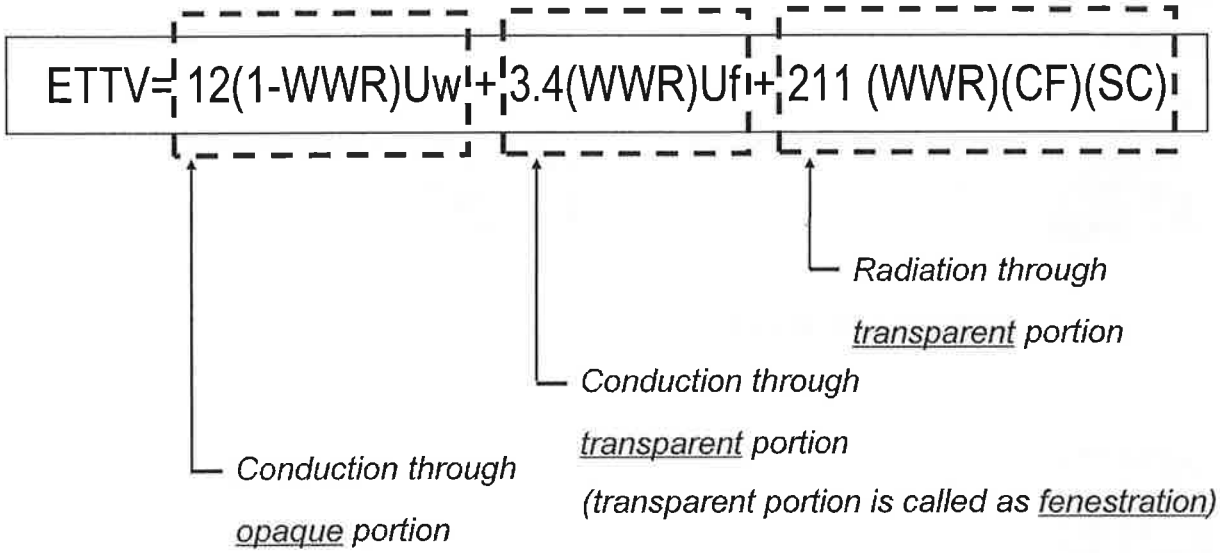
Uf = thermal transmittance of fenestration ($W/m^2\,K$) — U value of glass. window frame is part of the window.

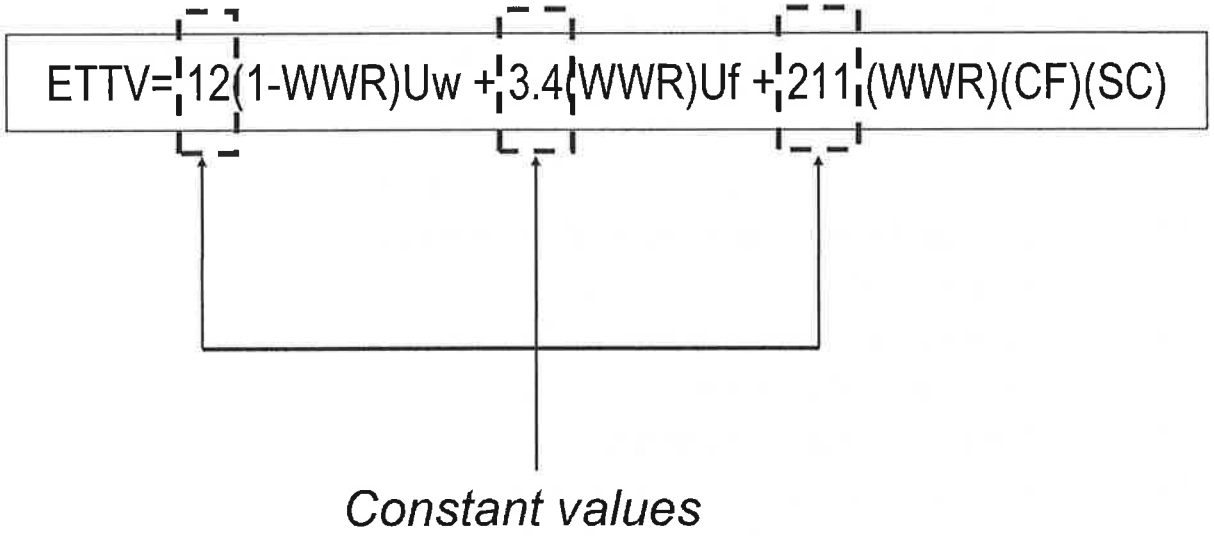
SC = Shading Coefficient of fenestration

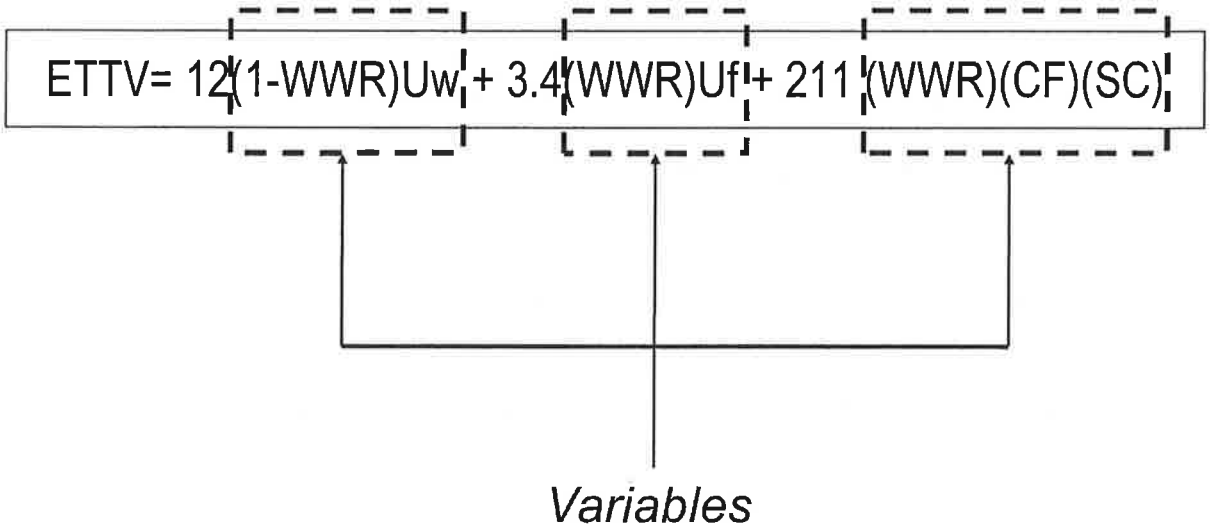
CF = solar Correction Factor of fenestration — depends on which direction the facade is facing.

ability of window to shade the solar radiation

eg. sunshade, material of glass


ETTV= 12(1-WWR)Uw + 3.4(WWR)Uf + 211 (WWR)(CF)(SC)
Radiation through transparent portion
Conduction through transparent portion
(transparent portion is called as fenestration)
Conduction through opaque portion


ETTV= 12(1-WWR)Uw + 3.4(WWR)Uf + 211 (WWR)(CF)(SC)
Constant values



Envelope Thermal Transfer Value

- If the envelope consists of various wall types, the calculation shall be expanded into its sub elements

$$ETTV = \frac{12(Aw_1 x Uw_1 + Aw_2 x Uw_2 + \ldots + Awn x Uwn) + 3.4(Af_1 x Uf_1 + Af_2 x Uf_2 + \ldots + Afn x Ufn) + 211(Af_1 x SC_1 + Af_2 x SC_2 + \ldots + Afn x SCn)}{Ao}$$

Envelope Thermal Transfer Value

Aw_1 = area of wall type 1 (Aw_2 = area of wall type 2 and so on.)

Uw_1 = U value of wall type 1 (Uw_2 = U value of wall type 2 and so on)

Af_1 = area of fenestration type 1 (Af_2 = area of fenestration type 2, etc.)

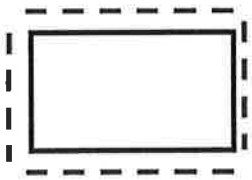
Uf_1 = U value of fenestration type 1 (Uf_2 = U value of fenestration type 2, etc.)

SC_1 = Shading Coefficient of fenestration type 1 (SC_2 = Shading Coefficient of fenestration type 2 and so on)

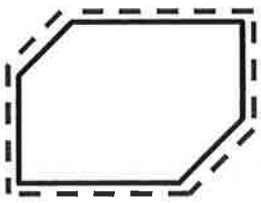
CF = Solar Correction Factor of building envelope orientation

Ao = total envelope area

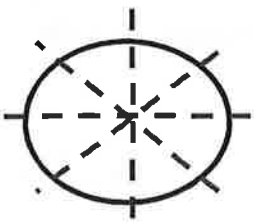
Envelope Thermal Transfer Value



4 x ETTV



6 x ETTV



8 x ETTV

- ETTV has to be calculated for different orientation using the formula

ETTV= 12(1-WWR)Uw + 3.4(WWR)Uf + 211 (WWR)(CF)(SC)

Envelope Thermal Transfer Value

- After calculating ETTV of each envelope direction, ETTV of the whole building envelope can be obtained by taking the weighted average of those values

$$ETTV = \frac{Ao_1 x ETTV_1 + Ao_2 x ETTV_2 + \ldots + Aon x ETTVn}{Ao_1 + Ao_2 + \ldots + Aon}$$

Envelope Thermal Transfer Value

Thermal Transmittance (U-Value)

the quantity of heat that flows through a unit area of a building section under steady state condition in unit time per unit temperature difference of the air on either side of the section (W/m2 K)

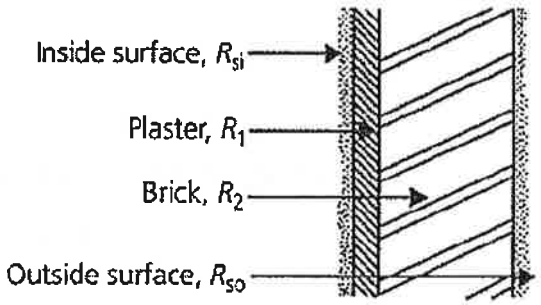
$$ETTV = 12(1-WWR)Uw + 3.4(WWR)Uf + 211\ (WWR)(CF)(SC)$$

Envelope Thermal Transfer Value

Thermal Transmittance (U-Value)

$$U = {}^{1}/_{Rt}$$

$$R = {}^{1}/_{C} = {}^{b}/_{K}$$

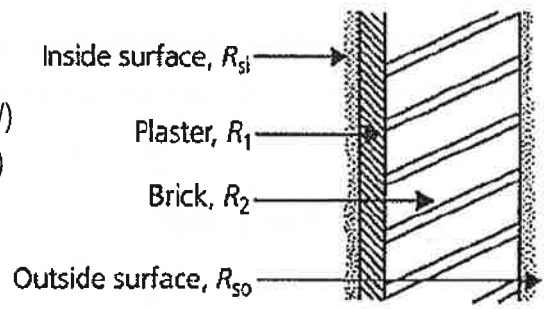


U = thermal transmittance ($W/m^2 K$)
Rt = total thermal resistance ($m^2 K / W$)
C = thermal conductance (W/m^2)
K = thermal conductivity (W/m K)
b = thickness of material (m)

Envelope Thermal Transfer Value

Thermal Transmittance (U-Value)

$$Rt = Ro + {}^{b1}/_{K1} + {}^{b2}/_{K2} + \ldots + {}^{bn}/_{Kn} + Ri$$



Ro= air film resistance of external surface ($m^2 K / W$)
Ri = air film resistance of internal surface ($m^2 K / W$)
K = thermal conductivity (W/m K)
b = thickness of material (m)

$$Rt = Ro + {}^{b1}/_{K1} + Ra + \ldots + {}^{bn}/_{Kn} + Ri$$

Ra= thermal transmittance of air space ($m^2 K / W$)

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Envelope Thermal Transfer Value

Shading Coefficient

$$ETTV = 12(1-WWR)Uw + 3.4(WWR)Uf + 211\ (WWR)(CF)(SC)$$

$$SC = SC1 \times SC2$$

SC = Shading Coefficient of the fenestration system

SC1 = Shading Coefficient of glass

SC2 = effective Shading Coefficient of external shading devices

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Envelope Thermal Transfer Value

Shading Coefficient of the Glass (SC1)

$$SC1 = \frac{\text{Solar heat gain of any glass}}{\text{Solar heat gain through a 3 mm unshaded clear glass}}$$



3mm unshaded clear glass

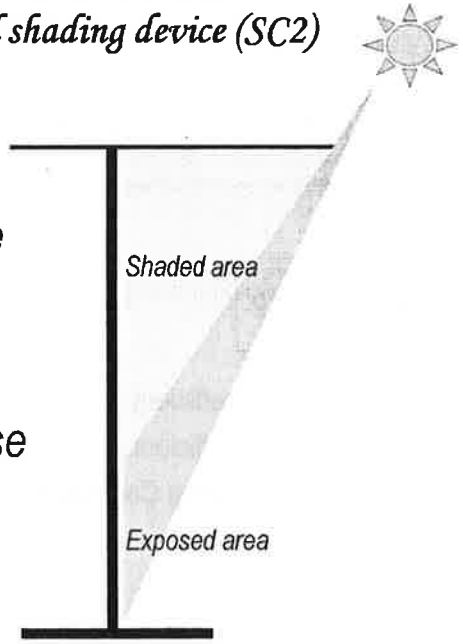


Any glass to use in the project

Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

- *Shaded areas receive only diffuse solar radiation*
- *Exposed areas receive both diffuse and direct solar radiation*



Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

$Q = (Ae \times I_D) + (A \times I_d)$

$Q = (Ae \times I_T) + (As \times I_d)$

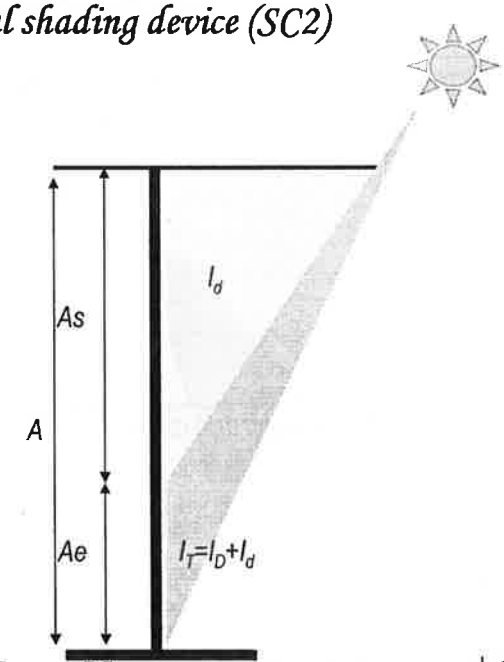
$= (Ae \times (I_D + I_d)) + (As \times I_d)$

$= (Ae \times I_D) + (Ae \times I_d) + (As \times I_d)$

$= Ae \times I_D + (Ae + As) \times I_d$

$= (Ae \times I_D) + (A \times I_d)$

where, $A = Ae + As$



Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

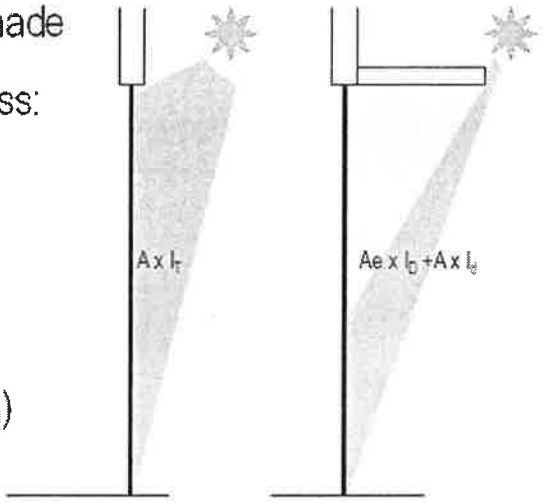
Shading Coefficient of Sunshade

For unshaded 3mm clear glass:

$Q = A \times I_T$

Therefore:

$$SC2 = \frac{(Ae \times I_D) + (A \times I_d)}{A \times I_T}$$



Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

$$SC2 = \frac{Ae \times I_D + A \times Id}{A \times I_T}$$

G = $^{Ae}/_{A}$

Q = solar heat gain

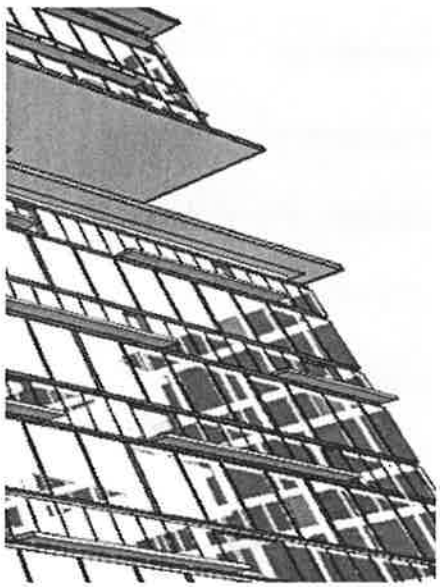
Ae = exposed area of window

As = shaded area of window

I_T = total radiation

I_D = direct radiation

Id = diffuse radiation



Envelope Thermal Transfer Value

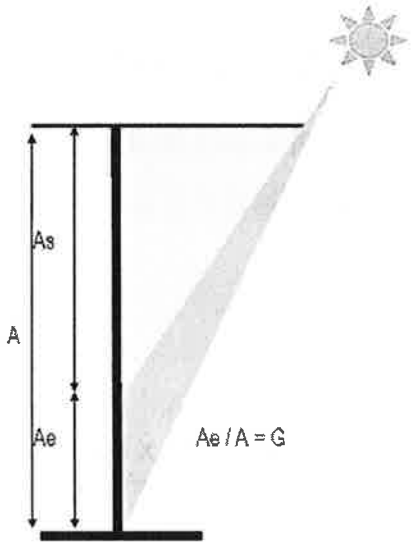
Shading Coefficient of the external shading device (SC2)

Shading Coefficient of Sunshade

$\frac{Ae}{A} = G$

$$SC2 = \frac{(Ae \times I_D) + (A \times I_d)}{A \times I_T}$$

$$SC2 = \frac{(G \times I_D) + I_d}{I_T}$$



Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

G depends on :

- *Position of sunshade*
- *Length of sunshade*
- *Tilt of sunshade*
- *orientation of fenestration*
- *sun position*

Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

- *G changes along with time in a day*
- *G changes along with day in a year*
- *SC2 calculation to be done every hour in a day*
- *SC2 calculation to be done every representative day in a year (21st March, 22nd June, 23rd September, 22nd December)*
- *Sun position in 21st March ≈ 23rd September*

Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

SC2 calculation to be done every hour in a day

$$SC_{day} = \frac{\sum_{h=1}^{h=12}(A_e \times I_D + A \times I_d)_h}{\sum_{h=1}^{h=12}(A \times I_T)_h}$$

Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

SC2 calculation to be done representative day in a year

$$SC_2 = \frac{\Sigma_M(G \times I_D + I_d) + \Sigma_J(G \times I_D + I_d) + \Sigma_S(G \times I_D + I_d) + \Sigma_D(G \times I_D + I_d)}{\Sigma_M I_T + \Sigma_J I_T + \Sigma_S I_T + \Sigma_D I_T}$$

M = representative day in March

J = representative day in June

S = representative day in September

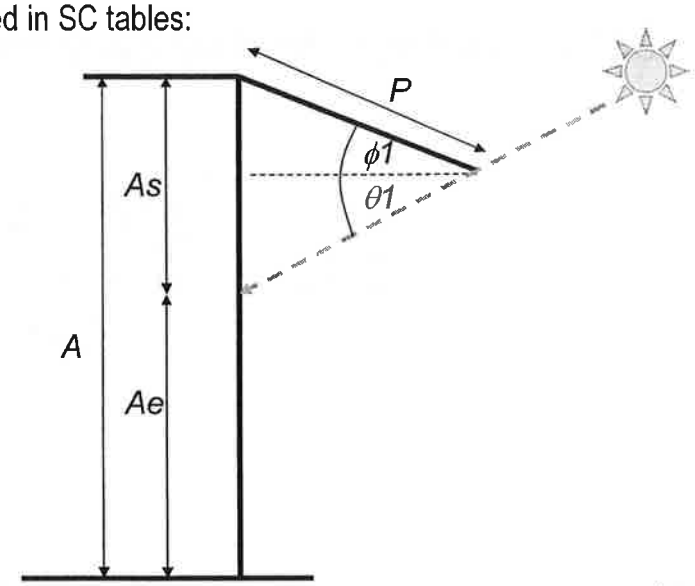
D = representative day in December

Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

- The calculation has been simplified in SC tables:
- Horizontal sunshade

$\underline{P} = R1$
A



Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

- The calculation has been simplified in SC tables:
- Horizontal sunshade

Orientation: East & West

R_1	0°	10°	20°	30°	40°	50°
0.1	0.9363	0.9268	0.9195	0.9147	0.9124	0.9129
0.2	0.8752	0.8565	0.8416	0.8309	0.8257	0.8257
0.3	0.8226	0.7947	0.7723	0.7563	0.7470	0.7448
0.4	0.7703	0.7330	0.7036	0.6820	0.6693	0.6664
0.5	0.7248	0.6842	0.6550	0.6231	0.6045	0.5946
0.6	0.6911	0.6424	0.6013	0.5691	0.5467	0.5349
0.7	0.6574	0.6006	0.5559	0.5249	0.5012	0.4851
0.8	0.6237	0.5693	0.5273	0.4923	0.4651	0.4457
0.9	0.5998	0.5463	0.4991	0.4608	0.4389	0.4237
1.0	0.5827	0.5232	0.4727	0.4442	0.4222	0.4062
1.1	0.5656	0.5002	0.4587	0.4296	0.4075	0.4010
1.2	0.5485	0.4828	0.4468	0.4151	0.4036	0.3969
1.3	0.5314	0.4739	0.4349	0.4089	0.3999	0.3963
1.4	0.5156	0.4650	0.4230	0.4059	0.3969	0.3963
1.5	0.5051	0.4561	0.4147	0.4029	0.3963	0.3963
1.6	0.4995	0.4472	0.4123	0.3999	0.3963	0.3963
1.7	0.4939	0.4383	0.4101	0.3974	0.3963	0.3963
1.8	0.4882	0.4294	0.4079	0.3963	0.3963	0.3963

Orientation: North & South

R_1	0°	10°	20°	30°	40°	50°
0.1	0.9380	0.9330	0.9300	0.9291	0.9303	0.9336
0.2	0.8773	0.8674	0.8613	0.8595	0.8619	0.8685
0.3	0.8167	0.8017	0.7927	0.7899	0.7935	0.8033
0.4	0.7560	0.7392	0.7288	0.7245	0.7263	0.7382
0.5	0.7210	0.7080	0.7001	0.6950	0.6927	0.6938
0.6	0.7041	0.6921	0.6848	0.6804	0.6774	0.6760
0.7	0.6923	0.6842	0.6775	0.6723	0.6689	0.6672
0.8	0.6871	0.6779	0.6702	0.6661	0.6641	0.6626
0.9	0.6819	0.6718	0.6670	0.6643	0.6621	0.6604
1.0	0.6767	0.6690	0.6655	0.6625	0.6600	0.6583
1.1	0.6731	0.6678	0.6640	0.6607	0.6584	0.6577
1.2	0.6713	0.6667	0.6625	0.6589	0.6577	0.6577
1.3	0.6705	0.6656	0.6611	0.6582	0.6577	0.6577
1.4	0.6698	0.6644	0.6596	0.6577	0.6577	0.6577
1.5	0.6690	0.6633	0.6588	0.6577	0.6577	0.6577
1.6	0.6683	0.6622	0.6582	0.6577	0.6577	0.6577
1.7	0.6675	0.6610	0.6577	0.6577	0.6577	0.6577

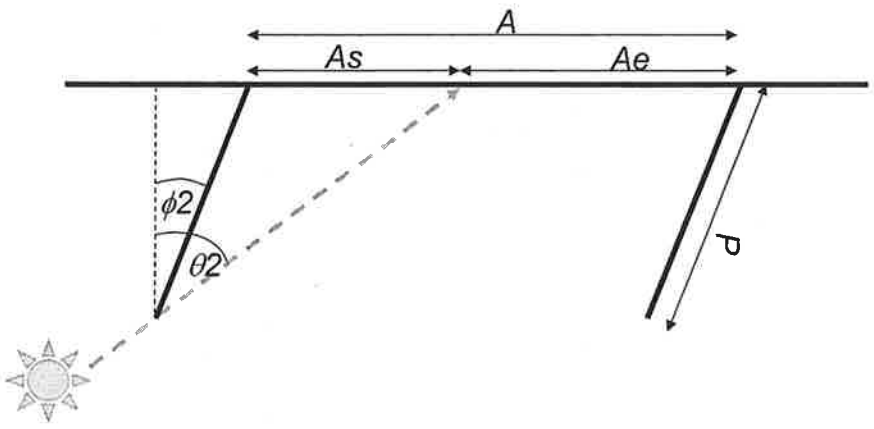
Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

- The calculation has been simplified in SC tables:
- Vertical sunshade

$\underline{P} = R2$

A



Envelope Thermal Transfer Value

Shading Coefficient of the external shading device (SC2)

- The calculation has been simplified in SC tables:
- Vertical sunshade

Orientation: East & West

R_2	0°	10°	20°	30°	40°	50°
0.1	0.9805	0.9751	0.9704	0.9653	0.9584	0.9520
0.2	0.9607	0.9499	0.9406	0.9302	0.9166	0.9038
0.3	0.9409	0.9247	0.9108	0.8952	0.8747	0.8555
0.4	0.9223	0.9007	0.8821	0.8614	0.8338	0.8078
0.5	0.9047	0.8774	0.8537	0.8275	0.7931	0.7606
0.6	0.8870	0.8543	0.8259	0.7939	0.7523	0.7133
0.7	0.8694	0.8313	0.7980	0.7616	0.7129	0.6671
0.8	0.8518	0.8090	0.7726	0.7312	0.6753	0.6227
0.9	0.8348	0.7884	0.7476	0.7014	0.6408	0.5823
1.0	0.8193	0.7678	0.7233	0.6747	0.6098	0.5493
1.1	0.8057	0.7471	0.7015	0.6511	0.5850	0.5184
1.2	0.7921	0.7287	0.6810	0.6320	0.5605	0.4880
1.3	0.7785	0.7120	0.6631	0.6135	0.5361	0.4633
1.4	0.7654	0.6960	0.6482	0.5949	0.5120	0.4577
1.5	0.7541	0.6826	0.6334	0.5764	0.4899	0.4526
1.6	0.7441	0.6696	0.6187	0.5579	0.4820	0.4474
1.7	0.7349	0.6589	0.6042	0.5397	0.4790	0.4422

Orientation: North & South

R_2	0°	10°	20°	30°	40°	50°
0.1	0.9526	0.9534	0.9549	0.9571	0.9606	0.9638
0.2	0.9066	0.9082	0.9110	0.9155	0.9225	0.9289
0.3	0.8605	0.8630	0.8672	0.8739	0.8844	0.8940
0.4	0.8144	0.8177	0.8236	0.8325	0.8463	0.8591
0.5	0.7752	0.7800	0.7892	0.8005	0.8159	0.8277
0.6	0.7540	0.7563	0.7632	0.7768	0.7950	0.8078
0.7	0.7379	0.7434	0.7464	0.7560	0.7771	0.7920
0.8	0.7290	0.7306	0.7348	0.7423	0.7637	0.7807
0.9	0.7202	0.7230	0.7269	0.7319	0.7507	0.7699
1.0	0.7114	0.7183	0.7190	0.7246	0.7388	0.7595
1.1	0.7060	0.7137	0.7144	0.7173	0.7308	0.7523
1.2	0.7022	0.7091	0.7098	0.7099	0.7251	0.7451
1.3	0.7000	0.7045	0.7053	0.7055	0.7206	0.7379
1.4	0.6977	0.6999	0.7007	0.7022	0.7173	0.7307
1.5	0.6954	0.6961	0.6981	0.7003	0.7141	0.7236
1.6	0.6932	0.6939	0.6960	0.6983	0.7109	0.7173
1.7	0.6909	0.6916	0.6940	0.6964	0.7077	0.7131

Envelope Thermal Transfer Value

Solar Correction Factors for Walls

$$ETTV = 12(1-WWR)Uw + 3.4(WWR)Uf + 211\,(WWR)(CF)(SC)$$

Pitch (°)	Orientation							
	N	NE	E	SE	S	SW	W	NW
70	1.17	1.33	1.47	1.35	1.21	1.41	1.56	1.38
75	1.07	1.23	1.37	1.25	1.11	1.32	1.47	1.28
80	0.98	1.14	1.30	1.16	1.01	1.23	1.39	1.20
85	0.89	1.05	1.21	1.07	0.92	1.14	1.31	1.11
90	0.80	0.97	1.13	0.98	0.83	1.06	1.23	1.03
95	0.73	0.90	1.05	0.91	0.76	0.99	1.15	0.96
100	0.67	-.83	0.97	0.84	0.70	0.92	1.08	0.89
105	0.62	0.77	0.90	0.78	0.65	0.86	1.01	0.83
110	0.59	0.72	0.83	0.72	0.61	0.80	0.94	0.78
115	0.57	0.67	0.77	0.67	0.58	0.75	0.87	0.73
120	0.55	0.63	0.72	0.63	0.56	0.71	0.81	0.69

Envelope Thermal Transfer Value

Example of calculation of ETTV at North facade:

Opaque area = 1000 m2

Glass area = 2000 m2

Wall U value = 2.5 W/m2K

Glass U value = 2.4 W/m2K

Glass SC = 0.3

CF = 0.8

ETTV =12(1-WWR)Uw + 3.4(WWR)Uf + 211 (WWR)(CF)(SC)

ETTV = 12(1-2/3)2.5 + 3.4(2/3)2.4+ 211 (2/3)(0.8)(0.3)

ETTV = 49.2 W/m2

↑ 2000 m² / 3000 m²

Total area = 1000 + 2000 = 3000 m²

Envelope Thermal Transfer Value

Example of total ETTV calculation:

South ETTV = 60 W/m2

South façade = 1000 m2 ✓

North ETTV = 55 W/m2

North façade = 1200 m2 ✓

East ETTV = 40 W/m2

East Façade = 600 m2 ✓

West ETTV = 35 W/m2

West Façade = 700 m2 ✓

$$ETTV = \frac{1000x60 + 1200x55 + 600x40 + 700x35}{1000 + 1200 + 600 + 700} = 49.85 \text{ W/m2}$$

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Envelope Thermal Transfer Value

Strategy:

Make sure the most determining variables is low enough.

All variables involved in ETTV:

- WWR
- Uw
- Uf
- SC
- CF

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Envelope Thermal Transfer Value

Example of East Façade ETTV

BASE CASE

window : 50% of total façade

window : tinted glass

opaque façade : opaque façade is made from brickwall + plaster

WWR	Uw	Uf	CF	SC
0.5	2.44	5.7	1.13	0.7

12(1-WWR)Uw	3.4(WWR)Uf	211(WWR)(CF)(SC)	**ETTV**
14.64	9.69	83.45	**107.78**

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Envelope Thermal Transfer Value

Example of East Façade ETTV

Scenario 1

window : 50% of total façade

window : tinted glass

opaque façade **: opaque façade is made from aluminium cladding + 50mm rockwool**

WWR	Uw	Uf	CF	SC
0.5	**0.55**	5.7	1.13	0.7

12(1-WWR)Uw	3.4(WWR)Uf	211(WWR)(CF)(SC)	**ETTV**
3.3	9.69	83.45	**96.44**

Uw reduction = 77.5%

ETTV Reduction = 10.5%

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Envelope Thermal Transfer Value

Example of East Façade ETTV

Scenario 2

window : 50% of total façade

window : tinted **double glazed**

opaque façade : opaque façade is made from brickwall + plaster

WWR	Uw	Uf	CF	SC
0.5	2.44	**1.5**	1.13	0.7

12(1-WWR)Uw	3.4(WWR)Uf	211(WWR)(CF)(SC)	**ETTV**
14.64	2.55	83.45	**100.64**

Uf reduction = 73.7%

ETTV reduction = 6.6%

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Envelope Thermal Transfer Value

Example of East Façade ETTV

Scenario 3

window **: 15% of total façade**

window : tinted glass

opaque façade : opaque façade is made from brickwall + plaster

WWR	Uw	Uf	CF	SC
0.15	2.44	5.7	1.13	0.7

12(1-WWR)Uw	3.4(WWR)Uf	211(WWR)(CF)(SC)	**ETTV**
24.888	2.907	25.035	**52.83**

WWR reduction = 70.0%

ETTV reduction = 51.0%

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Envelope Thermal Transfer Value

Example of East Façade ETTV

Scenario 4

window : 50% of total façade ← BCA new requirement is less than 20%.

window **: reflective glass (19% reflectance)**

opaque façade : opaque façade is made from brickwall + plaster

WWR	Uw	Uf	CF	SC
0.5	2.44	5.7	1.13	**0.26**

12(1-WWR)Uw	3.4(WWR)Uf	211(WWR)(CF)(SC)	**ETTV**
14.64	9.69	31	**55.33**

SC reduction = 62.9%

ETTV reduction = 48.7%

Envelope Thermal Transfer Value

Example of East Façade ETTV

Scenario 5

Window : 50% of total façade

window **: low-e DGU**

opaque façade : opaque façade is made from brickwall + plaster

WWR	Uw	Uf	CF	SC
0.5	2.44	1.6	1.13	**0.26**

12(1-WWR)Uw	3.4(WWR)Uf	211(WWR)(CF)(SC)	**ETTV**
14.64	2.72	31	**48.36**

SC reduction = 62.9% U Value reduction = 71.9%

ETTV reduction = 55.1%

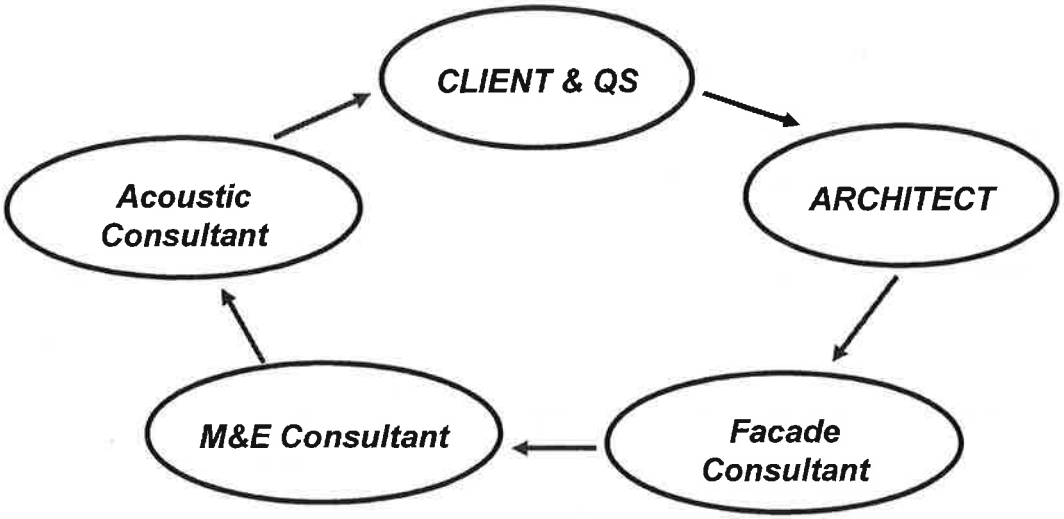
Envelope Thermal Transfer Value

Strategy:

- Minimize WWR, especially at orientation with high CF (East and West) facades
- Minimize SC
  - SC of glass
  - SC of sunshade

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Envelope Thermal Transfer Value

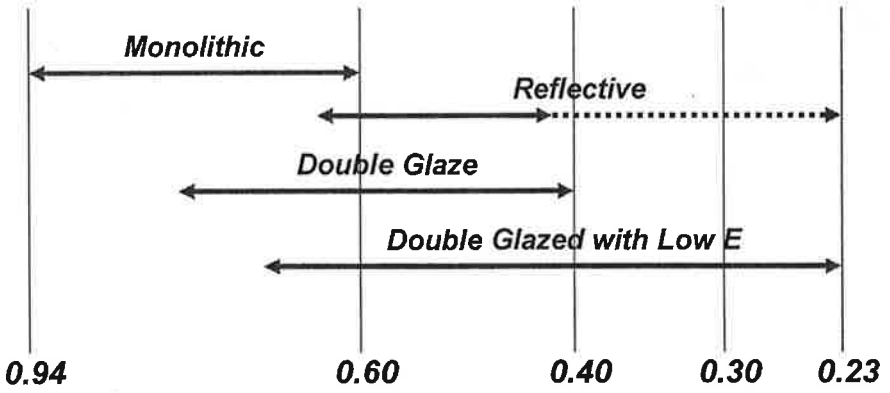


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Envelope Thermal Transfer Value

Shading Coefficient of the Glass (SC1)

- SC of Glass
  - Glass thickness → no significant impact
  - Glass coating and double glazing → significant impact



Monolithic Glass Performance Data[1,10]

Product	Nominal Glass Thickness		Visible Light[2]			Total Solar Energy[2]			U-Factor[5]						Solar Heat Gain Coeffi-cient[7]	Shading Coeffi-cient[8]
			Trans-mittance[3]	Reflectance[4] %		Trans-mittance[3]	Reflect-ance[4]	UV Trans-mittance[2]	U.S. Summer		U.S. Winter		European[6]			
	in.	mm	%	Outside	Inside	%	%	%	Air	Argon	Air	Argon	Air	Argon		
Pilkington Uncoated Float Glass																
Optifloat Clear	3/32	2.5	90	8	8	86	8	75	0.95	--	1.05	--	5.9	--	0.87	1.00
	1/8	3	90	8	8	84	8	72	0.94	--	1.04	--	5.8	--	0.86	0.99
	5/32	4	89	8	8	81	7	68	0.94	--	1.04	--	5.8	--	0.84	0.97
	3/16	5	89	8	8	80	7	65	0.93	--	1.03	--	5.8	--	0.83	0.96
	1/4	6	88	8	8	77	7	62	0.93	--	1.02	--	5.7	--	0.81	0.94
	5/16	8	87	8	8	73	7	57	0.92	--	1.01	--	5.7	--	0.79	0.91
	3/8	10	86	8	8	70	7	54	0.91	--	1.00	--	5.6	--	0.77	0.88
	1/2	12	84	8	8	64	6	49	0.89	--	0.98	--	5.5	--	0.73	0.84
	5/8	16	83	8	8	59	6	45	0.88	--	0.97	--	5.4	--	0.70	0.81
	3/4	19	81	7	7	55	6	41	0.86	--	0.95	--	5.3	--	0.67	0.78
Optifloat Grey Tint	1/8	3	61	6	6	59	6	35	0.94	--	1.04	--	5.8	--	0.69	0.8
	3/16	5	50	6	6	48	5	26	0.93	--	1.03	--	5.8	--	0.62	0.71
	1/4	6	43	5	5	40	5	20	0.93	--	1.02	--	5.7	--	0.57	0.66
	5/16	8	33	5	5	31	5	14	0.92	--	1.01	--	5.7	--	0.50	0.59
	3/8	10	28	5	5	26	5	11	0.91	--	1.00	--	5.6	--	0.47	0.55
	1/2	12	19	4	4	17	4	7	0.89	--	0.98	--	5.5	--	0.42	0.49
Optifloat Bronze Tint	1/8	3	68	6	6	65	6	37	0.94	--	1.04	--	5.8	--	0.73	0.84
	3/16	5	59	6	6	55	6	28	0.93	--	1.03	--	5.8	--	0.67	0.77
	1/4	6	53	5	5	49	5	23	0.93	--	1.02	--	5.7	--	0.62	0.72
	5/16	8	44	5	5	39	5	16	0.92	--	1.01	--	5.7	--	0.56	0.65
	3/8	10	39	5	5	34	5	13	0.91	--	1.00	--	5.6	--	0.53	0.61
	1/2	12	29	5	5	25	4	8	0.89	--	0.98	--	5.5	--	0.47	0.55
Optifloat Blue-Green Tint	1/4	6	75	7	7	48	5	31	0.93	--	1.02	--	5.7	--	0.62	0.72
	5/16	8	70	7	7	40	5	25	0.92	--	1.01	--	5.7	--	0.57	0.66
	3/8	10	67	6	6	36	5	21	0.91	--	1.00	--	5.6	--	0.54	0.62

Insulating Glass Performance Data[1,10]

[Insulating units constructed of equal glass thicknesses and 1/2" (12.7mm) airspace]

Product	Nominal Glass Thickness		Visible Light[2]			Total Solar Energy[2]			U-Factor[5]						Solar Heat Gain Coeffi-cient[7]	Shading Coeffi-cient[8]
			Trans-mittance[3]	Reflectance[4] %		Trans-mittance[3]	Reflec-ance[4]	UV Trans-mittance[2]	U.S. Summer		U.S. Winter		European[6]			
	in.	mm	%	Outside	Inside	%	%	%	Air	Argon	Air	Argon	Air	Argon		
Pilkington Uncoated Float Glass Outer Lite and Clear Float Glass Inner Lite																
Optifloat Clear	3/32	2.5	82	15	15	74	14	61	0.51	--	0.48	--	2.8	--	0.78	0.90
	1/8	3	81	15	15	71	13	57	0.51	--	0.48	--	2.8	--	0.76	0.88
	5/32	4	80	15	15	67	12	52	0.50	--	0.48	--	2.8	--	0.74	0.85
	3/16	5	79	15	15	64	12	50	0.50	--	0.48	--	2.8	--	0.72	0.83
	1/4	6	78	14	14	60	12	46	0.50	--	0.47	--	2.8	--	0.70	0.81
Optifloat Grey Tint	1/8	3	55	9	13	50	9	29	0.51	--	0.48	--	2.8	--	0.58	0.67
	3/16	5	45	8	13	39	7	21	0.50	--	0.48	--	2.8	--	0.50	0.58
	1/4	6	38	7	12	32	6	16	0.50	--	0.47	--	2.8	--	0.44	0.51
Optifloat Bronze Tint	1/8	3	62	10	13	55	9	31	0.51	--	0.48	--	2.8	--	0.63	0.72
	3/16	5	53	9	13	45	8	23	0.50	--	0.48	--	2.8	--	0.55	0.64
	1/4	6	47	8	12	38	7	18	0.50	--	0.47	--	2.8	--	0.50	0.58
Optifloat Blue-Green Tint	1/4	6	66	12	14	39	8	25	0.50	--	0.47	--	2.8	--	0.50	0.58
EverGreen High-Performance Tint	1/8	3	69	12	14	42	8	23	0.51	--	0.48	--	2.8	--	0.51	0.59
	3/16	5	65	11	14	35	7	18	0.50	--	0.48	--	2.8	--	0.46	0.53
	1/4	6	58	10	13	27	6	11	0.50	--	0.47	--	2.8	--	0.39	0.45
Arctic Blue High-Performance Tint	1/4	6	49	8	13	28	6	18	0.50	--	0.47	--	2.8	--	0.40	0.46
SuperGrey High-Performance Tint	1/8	3	23	5	12	19	5	6	0.51	--	0.48	--	2.8	--	0.32	0.37
	3/16	5	11	4	12	9	4	2	0.50	--	0.48	--	2.8	--	0.24	0.28
	1/4	6	8	4	11	6	4	1	0.50	--	0.47	--	2.8	--	0.21	0.25

Energy Advantage™ Low-E Insulating Glass Performance Data[1,10]

[Insulating units constructed of equal glass thicknesses and 1/2" (12.7mm) airspace]

Product	Nominal Glass Thickness		Visible Light[2]			Total Solar Energy[2]			U-Factor[5]						Solar Heat Gain Coeffi-cient[7]	Shading Coeffi-cient[8]
			Trans-mittance[3]	Reflectance[4] %		Trans-mittance[3]	Reflect-ance[4]	UV Trans-mittance[2]	U.S. Summer		U.S. Winter		European[6]			
	in.	mm	%	Outside	Inside	%	%	%	Air	Argon	Air	Argon	Air	Argon		
Pilkington Uncoated Float Glass Outer Lite and Energy Advantage™ Low-E Glass Inner Lite (#3 Surface)																
Optifloat Clear	3/32	2.5	76	18	17	62	17	48	0.33	0.28	0.34	0.29	1.9	1.6	0.73	0.84
	1/8	3	75	18	17	59	16	45	0.33	0.28	0.33	0.29	1.9	1.6	0.71	0.82
	5/32	4	74	17	16	56	16	42	0.33	0.28	0.33	0.29	1.9	1.6	0.69	0.80
	3/16	5	74	17	17	55	15	41	0.33	0.28	0.33	0.29	1.9	1.6	0.68	0.79
	1/4	6	73	17	16	52	14	36	0.33	0.28	0.33	0.29	1.8	1.6	0.66	0.76
	5/16	8	71	16	15	47	13	32	0.33	0.28	0.33	0.28	1.9	1.5	0.63	0.72
	3/8	10	69	16	15	44	12	30	0.32	0.28	0.33	0.28	1.9	1.5	0.60	0.70
Optifloat Grey Tint	1/8	3	50	10	15	41	11	24	0.33	0.28	0.33	0.29	1.8	1.6	0.53	0.61
	3/16	5	42	8	15	32	8	17	0.33	0.28	0.33	0.29	1.9	1.6	0.45	0.51
	1/4	6	35	7	14	27	7	13	0.33	0.28	0.33	0.29	1.9	1.6	0.39	0.45
Optifloat Bronze Tint	1/8	3	57	12	15	45	12	25	0.33	0.28	0.33	0.29	1.8	1.6	0.57	0.66
	3/16	5	49	10	15	38	10	19	0.33	0.28	0.33	0.29	1.8	1.6	0.50	0.58
	1/4	6	44	9	14	32	8	14	0.33	0.28	0.33	0.29	1.9	1.6	0.45	0.52
Optifloat Blue-Green Tint	1/4	6	62	13	15	34	9	20	0.33	0.28	0.33	0.29	1.9	1.6	0.45	0.52
EverGreen High-Performance Tint	1/8	3	64	14	16	35	9	18	0.33	0.28	0.33	0.29	1.8	1.6	0.46	0.53
	3/16	5	61	13	16	31	8	14	0.33	0.28	0.33	0.29	1.8	1.6	0.41	0.47
	1/4	6	54	11	14	24	7	9	0.33	0.28	0.33	0.29	1.9	1.6	0.34	0.39
Arctic Blue High-Performance Tint	1/4	6	45	9	14	24	7	14	0.33	0.28	0.33	0.29	1.9	1.6	0.35	0.40
SuperGrey High-Performance Tint	1/8	3	21	5	14	15	5	4	0.33	0.28	0.33	0.29	1.8	1.6	0.26	0.30
	3/16	5	10	4	14	7	4	2	0.33	0.28	0.33	0.29	1.7	1.6	0.18	0.21
	1/4	6	7	4	13	5	4	1	0.33	0.28	0.33	0.29	1.7	1.6	0.15	0.18

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Envelope Thermal Transfer Value

- SC of sunshade
  - orientation
  - Position
  - Length
  - Tilt

Envelope Thermal Transfer Value

- Sunshade orientation
  - Horizontal sunshade performs similarly at every orientation and always better than vertical sunshade
  - Vertical sunshade performs slightly better at North-South orientation than East-West orientation

Table 10: Effective Shading Coefficients of Horizontal Projection at Various Angles of Inclination

Orientation: North & South

R_1	0°	10°	20°	30°	40°	50°
0.1	0.9380	0.9330	0.9300	0.9291	0.9303	0.9336
0.2	0.8773	0.8674	0.8613	0.8595	0.8619	0.8685
0.3	0.8167	0.8017	0.7927	0.7899	0.7935	0.8033
0.4	0.7560	0.7392	0.7288	0.7245	0.7263	0.7382
0.5	0.7210	0.7080	0.7001	0.6950	0.6927	0.6938
0.6	0.7041	0.6921	0.6848	0.6804	0.6774	0.6760
0.7	0.6923	0.6842	0.6775	0.6723	0.8689	0.6672
0.8	0.6871	0.6779	0.6702	0.6661	0.6641	0.6626

Table 11: Effective Shading Coefficients of Horizontal Projection at Various Angles of Inclination

Orientation: East & West

R_1	0°	10°	20°	30°	40°	50°
0.1	0.9363	0.9268	0.9195	0.9147	0.9124	0.9129
0.2	0.8752	0.8565	0.8416	0.8309	0.8257	0.8257
0.3	0.8228	0.7947	0.7723	0.7563	0.7470	0.7448
0.4	0.7703	0.7330	0.7036	0.6820	0.6693	0.6664
0.5	0.7248	0.6842	0.6550	0.6231	0.6045	0.5946
0.6	0.6911	0.6424	0.6013	0.5691	0.5497	0.5349
0.7	0.6574	0.6006	0.5559	0.5249	0.5012	0.4851
0.8	0.6237	0.5693	0.5273	0.4923	0.4651	0.4467

3. ETTV – Affecting Factors

Shading Coefficient of Sunshade

- The calculation has been simplified in SC tables:
- Vertical sunshade

Orientation: East & West

R_2	0°	10°	20°	30°	40°	50°
0.1	0.9805	0.9751	0.9704	0.9653	0.9584	0.9520
0.2	0.9607	0.9499	0.9406	0.9302	0.9166	0.9038
0.3	0.9409	0.9247	0.9108	0.8952	0.8747	0.8555
0.4	0.9223	0.9007	0.8821	0.8614	0.8338	0.8078
0.5	0.9047	0.8774	0.8537	0.8275	0.7931	0.7606
0.6	0.8870	0.8543	0.8259	0.7939	0.7523	0.7133
0.7	0.8694	0.8313	0.7980	0.7616	0.7129	0.6671
0.8	0.8518	0.8090	0.7728	0.7312	0.6753	0.6227
0.9	0.8348	0.7884	0.7476	0.7014	0.6406	0.5823
1.0	0.8193	0.7678	0.7233	0.6747	0.6098	0.5493
1.1	0.8057	0.7471	0.7015	0.6511	0.5850	0.5184
1.2	0.7921	0.7287	0.6810	0.6320	0.5605	0.4880
1.3	0.7785	0.7120	0.6631	0.6135	0.5361	0.4633
1.4	0.7654	0.6960	0.6482	0.5949	0.5120	0.4577
1.5	0.7541	0.6826	0.6334	0.5764	0.4899	0.4526
1.6	0.7441	0.6696	0.6187	0.5579	0.4820	0.4474
1.7	0.7349	0.6589	0.6042	0.5397	0.4790	0.4422

Orientation: North & South

R_2	0°	10°	20°	30°	40°	50°
0.1	0.9526	0.9534	0.9549	0.9571	0.9606	0.9638
0.2	0.9066	0.9082	0.9110	0.9155	0.9225	0.9289
0.3	0.8605	0.8630	0.8672	0.8739	0.8844	0.8940
0.4	0.8144	0.8177	0.8236	0.8325	0.8463	0.8591
0.5	0.7752	0.7800	0.7892	0.8005	0.8159	0.8277
0.6	0.7540	0.7563	0.7632	0.7768	0.7950	0.8078
0.7	0.7379	0.7434	0.7464	0.7560	0.7771	0.7920
0.8	0.7290	0.7306	0.7348	0.7423	0.7637	0.7807
0.9	0.7202	0.7230	0.7269	0.7319	0.7507	0.7699
1.0	0.7114	0.7183	0.7190	0.7246	0.7388	0.7595
1.1	0.7060	0.7137	0.7144	0.7173	0.7308	0.7523
1.2	0.7022	0.7091	0.7098	0.7099	0.7251	0.7451
1.3	0.7000	0.7045	0.7053	0.7055	0.7206	0.7379
1.4	0.6977	0.6999	0.7007	0.7022	0.7173	0.7307
1.5	0.6954	0.6961	0.6981	0.7003	0.7141	0.7236
1.6	0.6932	0.6939	0.6960	0.6983	0.7109	0.7173
1.7	0.6909	0.6916	0.6940	0.6964	0.7077	0.7131

3. ETTV – Affecting Factors

Shading Coefficient of Sunshade

- Comparison at North-South facade
- Horizontal sunshade

Orientation: North & South

R_1	0°	10°	20°	30°	40°	50°
0.1	0.9380	0.9330	0.9300	0.9291	0.9303	0.9336
0.2	0.8773	0.8674	0.8613	0.8595	0.8619	0.8685
0.3	0.8167	0.8017	0.7927	0.7899	0.7935	0.8033
0.4	0.7560	0.7392	0.7288	0.7245	0.7263	0.7382
0.5	0.7210	0.7080	0.7001	0.6950	0.6927	0.6938
0.6	0.7041	0.6921	0.6848	0.6804	0.6774	0.6760
0.7	0.6913	0.6812	0.6775	0.6723	0.6689	0.6672
0.8	0.6771	0.6717	0.6702	0.6661	0.6641	0.6626
0.9	0.6711	0.6618	0.6670	0.6[illegible]	0.6[illegible]	0.6[illegible]
1.0	0.6767	0.6690	0.6665	0.6662	0.6[illegible]00	0.6[illegible]3
1.1	0.6711	0.6678	0.6667	0.6667	0.6658	0.6677
1.2	0.6713	0.6667	0.6665	0.6669	0.6[illegible]57	0.6677
1.3	0.6705	0.6656	0.6[illegible]11	0.6582	0.6577	0.6577
1.4	0.6698	0.6644	0.6596	0.6577	0.6577	0.6577
1.5	0.6690	0.6633	0.6588	0.6577	0.6577	0.6577
1.6	0.6683	0.6622	0.6582	0.6577	0.6577	0.6577
1.7	0.6675	0.6610	0.6577	0.6577	0.6577	0.6577

- Vertical sunshade

Orientation: North & South

R_2	0°	10°	20°	30°	40°	50°
0.1	0.9526	0.9534	0.9549	0.9571	0.9606	0.9638
0.2	0.9066	0.9082	0.9110	0.9155	0.9225	0.9289
0.3	0.8605	0.8630	0.8672	0.8739	0.8844	0.8940
0.4	0.8144	0.8177	0.8236	0.8325	0.8463	0.8591
0.5	0.7752	0.7800	0.7892	0.8005	0.8159	0.8277
0.6	0.7540	0.7563	0.7632	0.7768	0.7950	0.8078
0.7	0.7379	0.7434	0.7464	0.7560	0.7771	0.7920
0.8	0.7290	0.7306	0.7348	0.7423	0.7637	0.7807
0.9	0.7202	0.7230	0.7269	0.7319	0.7507	0.7699
1.0	0.7114	0.7183	0.7190	0.7246	0.7388	0.7595
1.1	0.7060	0.7137	0.7144	0.7173	0.7308	0.7523
1.2	0.7022	0.7091	0.7098	0.7099	0.7251	0.7451
1.3	0.7000	0.7045	0.7053	0.7055	0.7206	0.7379
1.4	0.6977	0.6999	0.7007	0.7022	0.7173	0.7307
1.5	0.6954	0.6961	0.6981	0.7003	0.7141	0.7236
1.6	0.6932	0.6939	0.6960	0.6983	0.7109	0.7173
1.7	0.6909	0.6916	0.6940	0.6964	0.7077	0.7131

Slightly Better

3. ETTV – Affecting Factors

Shading Coefficient of Sunshade

- Comparison at East-West facade
- Horizontal sunshade

Orientation: East & West

R_1	0°	10°	20°	30°	40°	50°
0.1	0.9363	0.9268	0.9195	0.9147	0.9124	0.9129
0.2	0.8752	0.8565	0.8416	0.8309	0.8257	0.8257
0.3	0.8228	0.7947	0.7723	0.7563	0.7470	0.7448
0.4	0.7703	0.7330	0.7036	0.6820	0.6693	0.6664
0.5	0.7248	0.6842	0.6550	0.6231	0.6045	0.5946
0.6	0.6911	0.6424	0.6013	0.5691	0.5467	0.5349
0.7	0.6571	0.6006	0.5559	0.5249	0.5012	0.4851
0.8	0.6237	0.5693	0.5273	0.4923	0.4651	0.4467
0.9	0.5918	0.5468	0.4991	0.4608	0.4319	0.4237
1.0	0.5627	0.5232	0.4727	0.4447	0.4172	0.4072
1.1	0.5356	0.5002	0.4587	0.4276	0.4075	0.3910
1.2	0.5185	0.4828	0.4468	0.4171	0.4036	0.3969
1.3	0.5091	0.4773	0.4349	0.4089	0.3999	0.3963
1.4	0.5150	0.4830	0.4230	0.4059	0.3963	0.3963
1.5	0.5051	0.4561	0.4147	0.4029	0.3963	0.3963
1.6	0.4995	0.4472	0.4123	0.3999	0.3963	0.3963
1.7	0.4939	0.4383	0.4101	0.3974	0.3963	0.3963
1.8	0.4882	0.4294	0.4079	0.3963	0.3963	0.3963

- Vertical sunshade

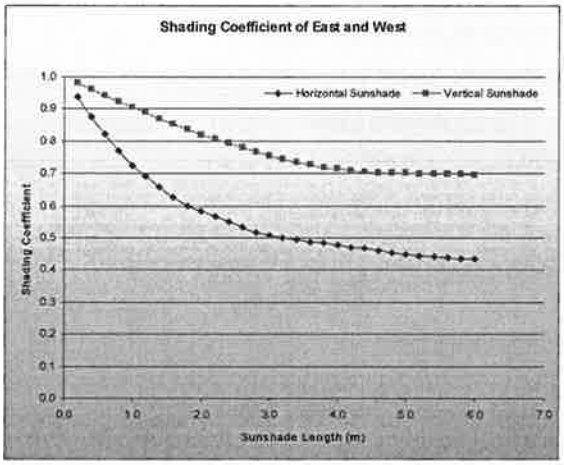
Orientation: East & West

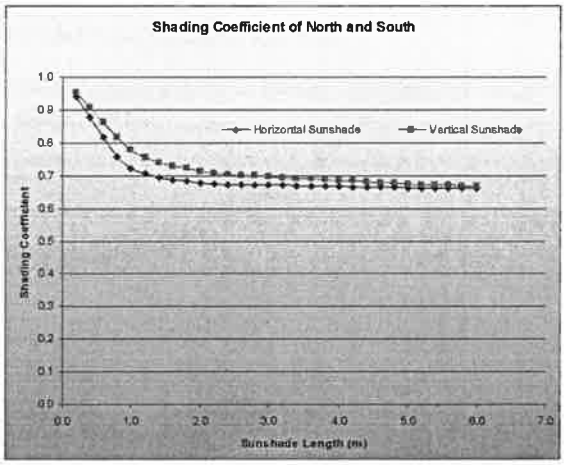
R_2	0°	10°	20°	30°	40°	50°
0.1	0.9805	0.9751	0.9704	0.9653	0.9584	0.9520
0.2	0.9607	0.9499	0.9406	0.9302	0.9166	0.9038
0.3	0.9409	0.9247	0.9108	0.8952	0.8747	0.8555
0.4	0.9223	0.9007	0.8821	0.8614	0.8338	0.8078
0.5	0.9047	0.8774	0.8537	0.8275	0.7931	0.7606
0.6	0.8870	0.8543	0.8259	0.7939	0.7523	0.7133
0.7	0.8694	0.8313	0.7980	0.7616	0.7129	0.6671
0.8	0.8518	0.8090	0.7728	0.7312	0.6753	0.6227
0.9	0.8348	0.7884	0.7476	0.7014	0.6406	0.5823
1.0	0.8193	0.7678	0.7233	0.6747	0.6098	0.5493
1.1	0.8057	0.7471	0.7015	0.6511	0.5850	0.5184
1.2	0.7921	0.7287	0.6810	0.6320	0.5605	0.4880
1.3	0.7785	0.7120	0.6631	0.6135	0.5361	0.4633
1.4	0.7654	0.6960	0.6482	0.5949	0.5120	0.4577
1.5	0.7541	0.6826	0.6334	0.5764	0.4899	0.4526
1.6	0.7441	0.6696	0.6187	0.5579	0.4820	0.4474
1.7	0.7349	0.6589	0.6042	0.5397	0.4790	0.4422

Much better

3. ETTV – Affecting Factors

Shading Coefficient of Sunshade

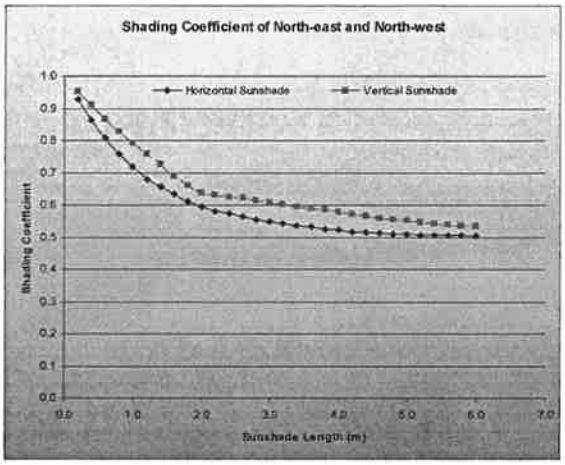


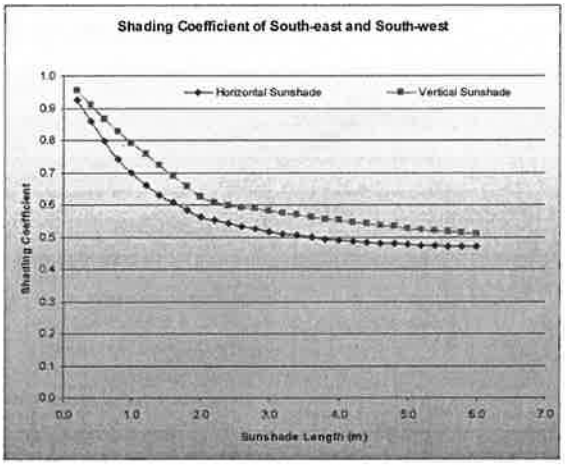


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3. ETTV – Affecting Factors

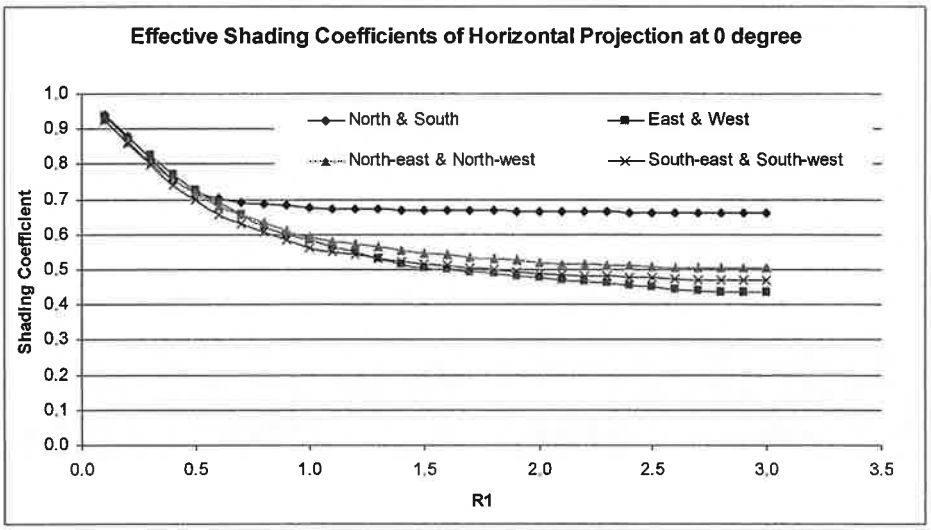
Shading Coefficient of Sunshade





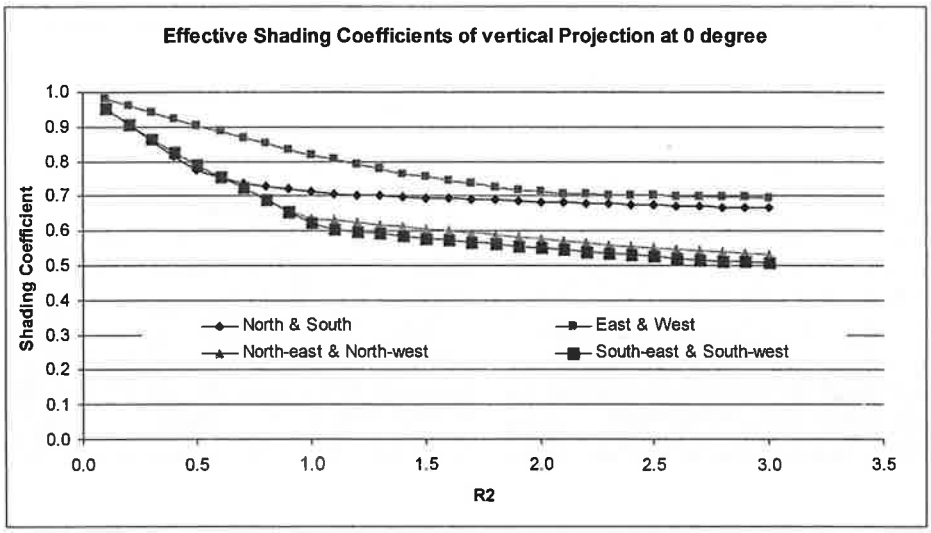
3. ETTV – Affecting Factors

Shading Coefficient of Sunshade



3. ETTV – Affecting Factors

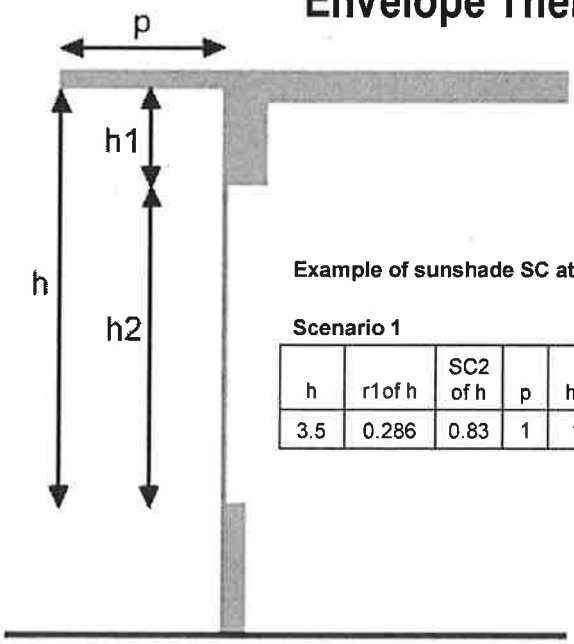
Shading Coefficient of Sunshade



Envelope Thermal Transfer Value

- Sunshade position
  - The closer the sunshade to window, the lower is the SC (better performance)

Envelope Thermal Transfer Value

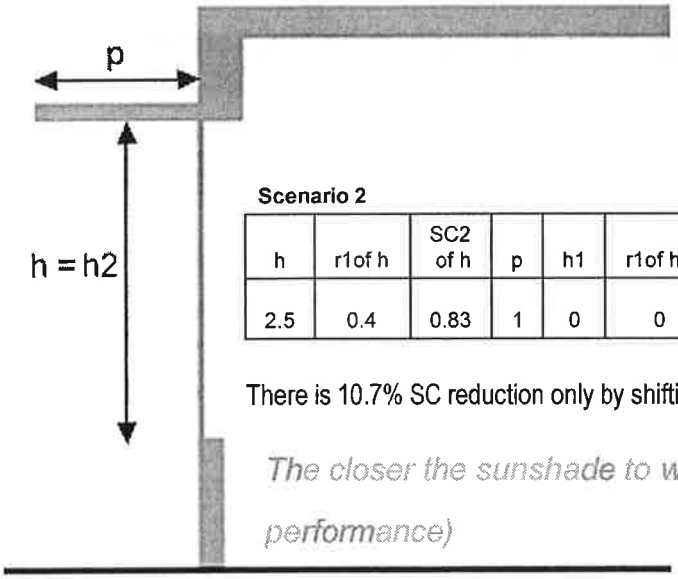


Example of sunshade SC at East Façade

Scenario 1

h	r1 of h	SC2 of h	p	h1	r1 of h1	SC2 of h1	h2	SC2 of h2= ((SC2ofh x h)-(SC2ofh1 xh1))/h2
3.5	0.286	0.83	1	1	1	0.58	2.5	**0.93**

Envelope Thermal Transfer Value



Scenario 2

h	r1of h	SC2 of h	p	h1	r1of h1	SC2 of h1	h2	SC2 of h2= ((SC2ofh x h)-(SC2ofh1 xh1))/h2
2.5	0.4	0.83	1	0	0	0	2.5	**0.83**

There is 10.7% SC reduction only by shifting down the sunshade closer to window

The closer the sunshade to window, the lower is the SC (better performance)

Envelope Thermal Transfer Value

- Complicated sunshade shape
  - Calculation by computational simulation

$$SC = \frac{Ae \times I_D + A \times Id}{A \times I_T}$$

→ Solar radiation on window with sunshade

→ Solar radiation on window without sunshade

G = $^{Ae}/_{A}$

Q = solar heat gain

Ae = exposed area of window

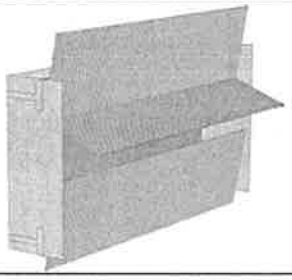
As = shaded area of window

I_T = total radiation

I_D = direct radiation

Id = diffuse radiation

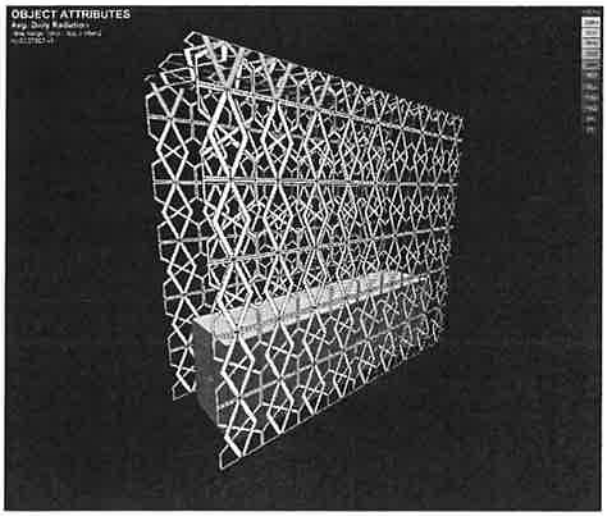
Envelope Thermal Transfer Value

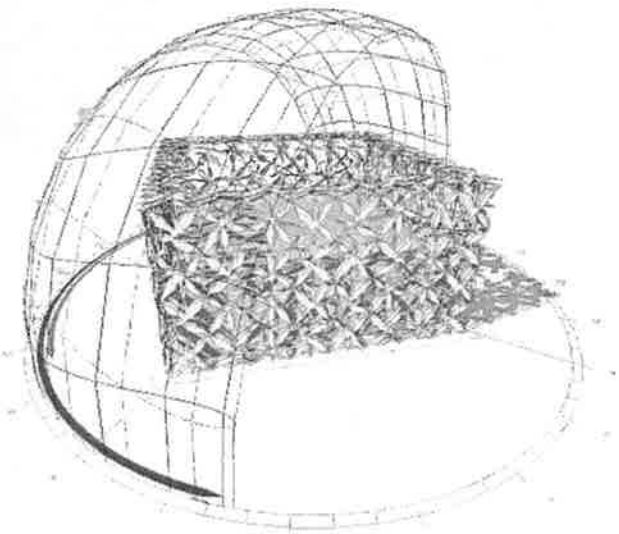
Façade	Daily (Averaged Across A Year) Solar Radiation Wh/m2		
	Without Screen (column A)	With Opened Screen (column B)	Shading Coefficient of Opened Screen (B/A)
			
SE (130 deg from N-clock wise)	1044.17	675.977	0.65
SW (220 deg from N-clock wise)	1059.11	685.854	0.65
NW (310 deg from N-clock wise)	1108.51	700.695	0.63

Comparison between solar radiation on window with sunshade and that without sunshade

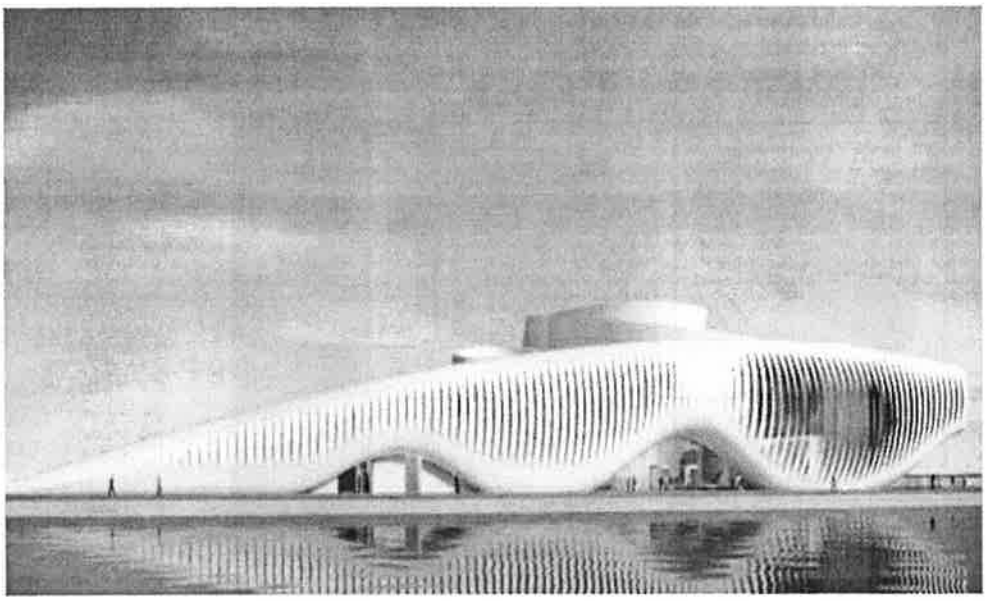
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Envelope Thermal Transfer Value

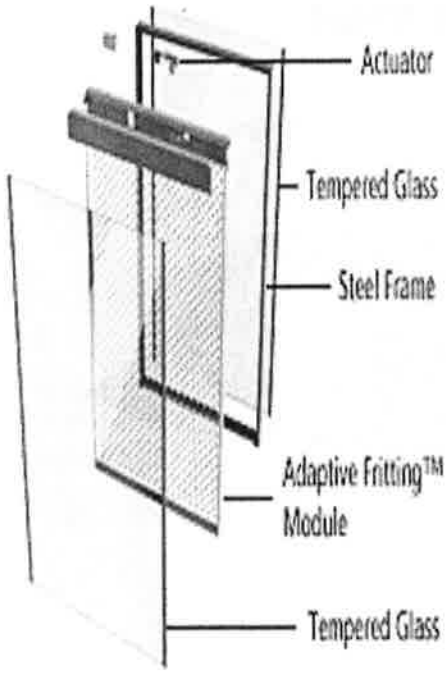


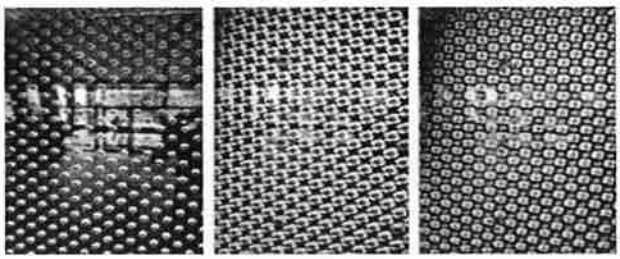


Envelope Thermal Transfer Value

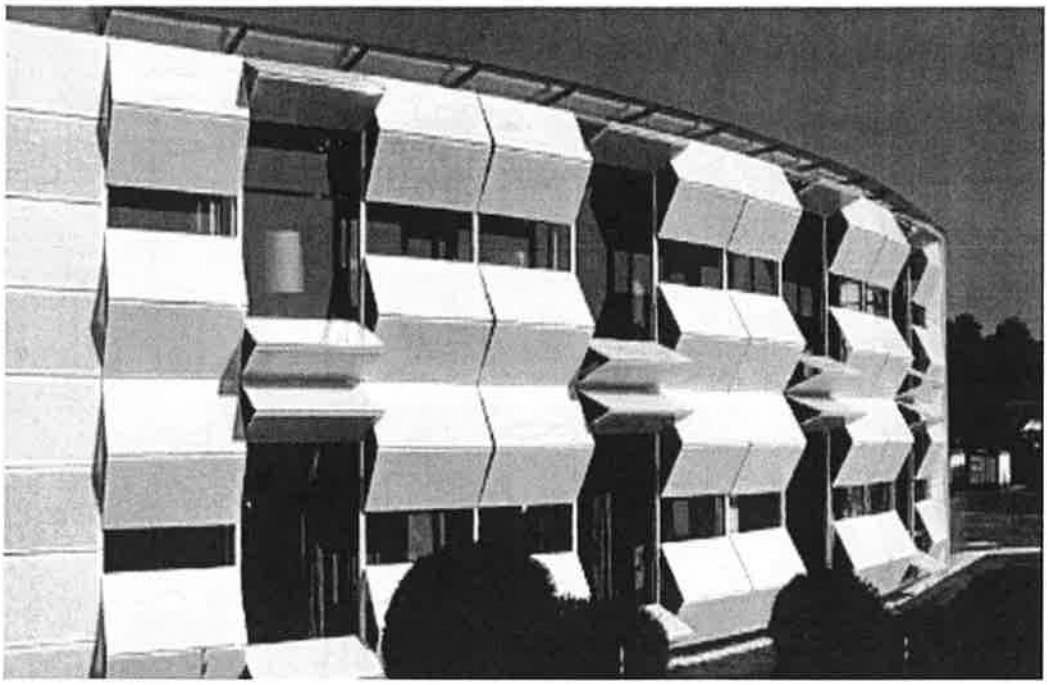


Responsive Design – Adaptive Fritting





- *Integrated glass unit with a custom moveable graphic pattern*
- *Panels can be composed of fritted **glass** or **plastics**, at scales ranging from 0.5 to 3 meters.*
- *Infinite Patterning Options*
  - *Images*
  - *Non-uniform fields or gradients*
  - *Organic patterns*
  - *Non-repeating patterns Performance is achieved by shifting a series of fritted glass layers*



Envelope Thermal Transfer Value

RETV= 3.4 (1-WWR)Uw + 1.3 (WWR)Uf + 58.6 (WWR)(CF)(SC)

Opaque Transparent

External facades of living, dining, study and bedroom are considered in RETV computation

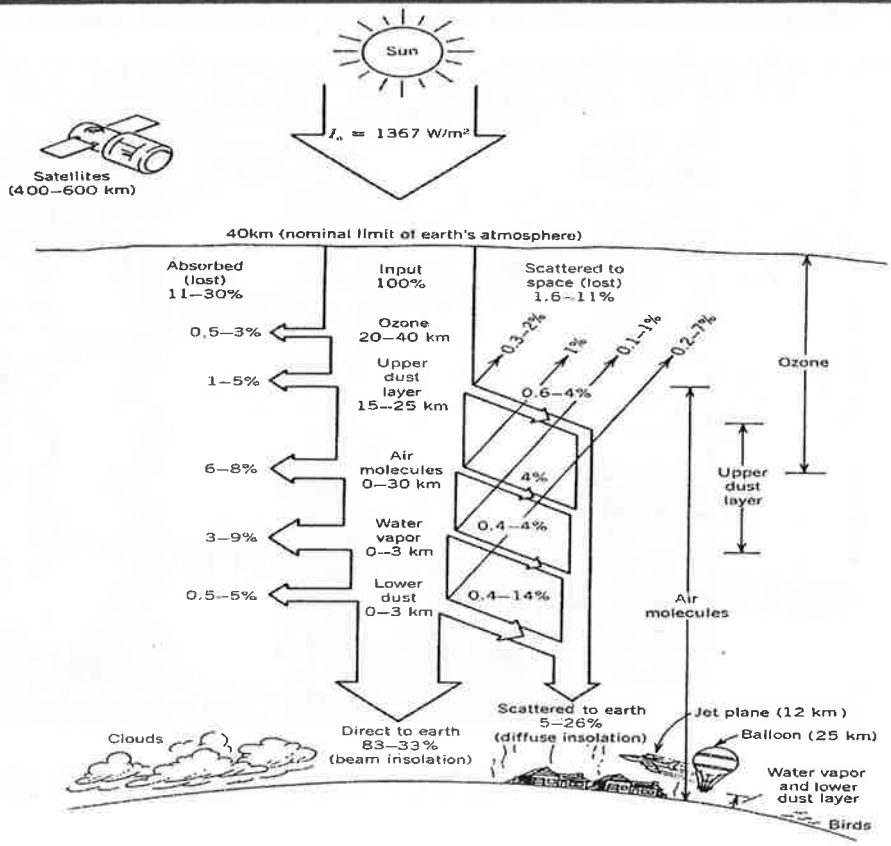
ETTV Guideline in BCA website :

http://www.bca.gov.sg/PerformanceBased/others/ETTV.pdf

For Residential:

RETV = Residential Envelope Transmission Value (max. 25 W/m2)

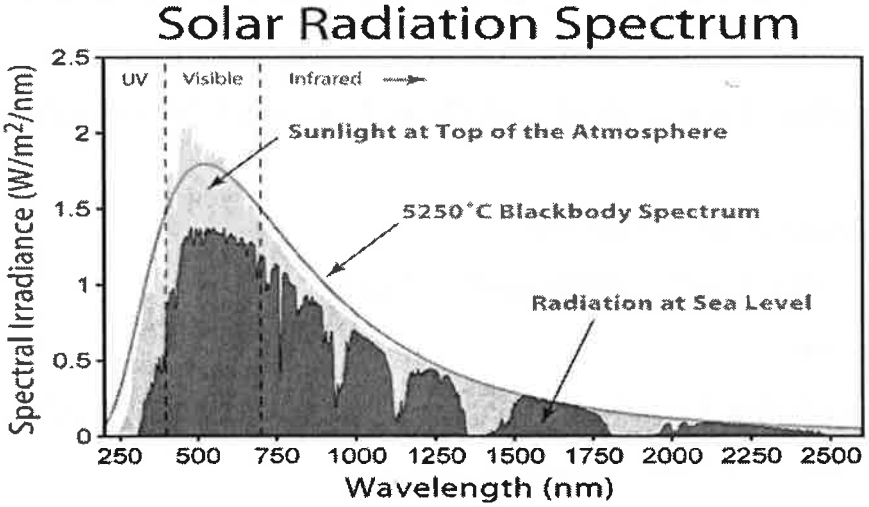
http://www.bca.gov.sg/PerformanceBased/others/RETV.pdf



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Daylighting

- Introduction
  - Daylight is the visible portion of radiation spectrum emitted from the sun.



Daylighting

- Advantage
  - reduce energy consumption

    reduce electrical lighting usage during daytime
  - Has perfect color rendering spectrum

    Color Rendering Index is a measure of how closely the lamp renders colors of object compared to a standard source. Daylight is considered as the standard.
  - Healthier light source

    Lacking of daylight can suppress melatonin hormone that causes symptoms of depression, fatigue, and loss of alertness

Daylighting

- Disadvantage
  - visible spectrum of solar radiation also comes together with the non-visible spectrum of solar radiation (ultraviolet and infrared).
  - The rest of the spectrums is not visually useful, it causes heat to the interior
  - Daylight may cause glare

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Daylighting

- Maximizing Daylight
  - Use spectrally selected glass (low-e) to filter the non-visible spectrum and to welcome the visible spectrum

    For example:
    - Reflective glass can have low SC value to reject heat, but it also reject the visible light. (less light transmission)
    - Low-e glass can have low SC value to reject heat and also welcome the visible light. (more light transmission)

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Daylighting

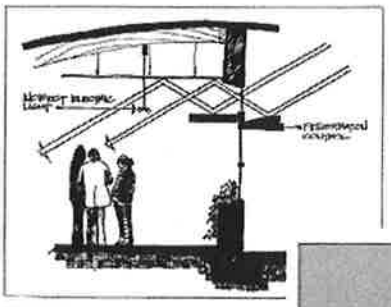
- Maximizing Daylight
  - Use of full height glass does not result in even light level in the interior.

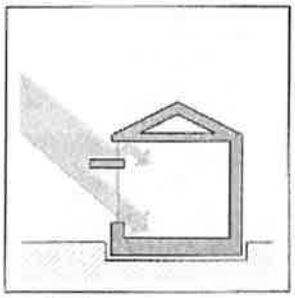
    Light level is much higher at the perimeter area and very much lower at the rear of the room.

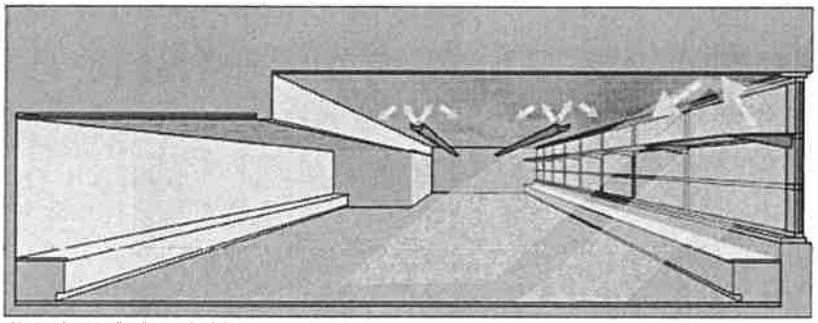
    Thus, daylight deflector helps to deliver daylight further to the rear of the room.

- *Light shelfs are useful to enhance day lighting in the interior space.*
- *It cuts off excessive brightness near windows and deflects day light deeper into the space.*
- *Helps in achieving better daylight to reach the dark interior space.*

Till now only 10m light penetration

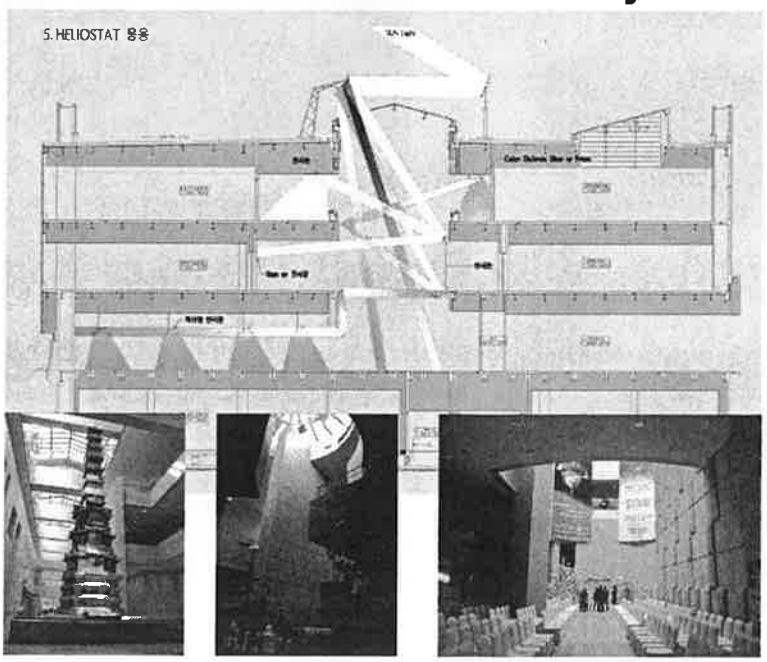


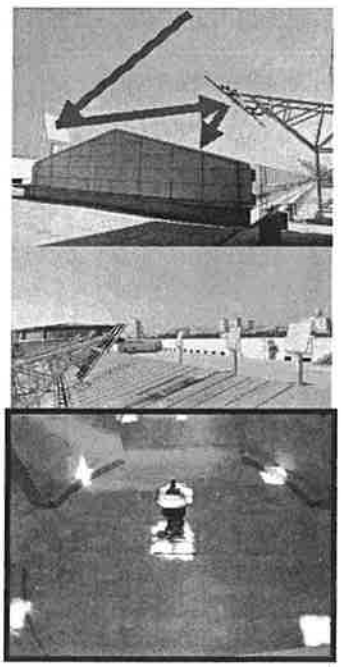




THE LIGHT SHELVES ON THE SOUTH SIDE OF THE BUILDING HELP BRING SUNLIGHT DEEPER INTO THE ROOM

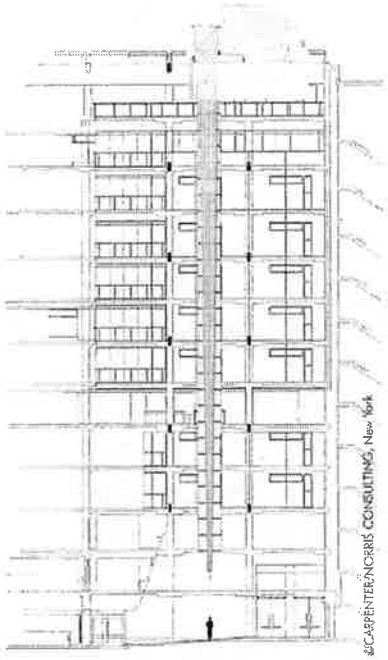
Mirror reflect system

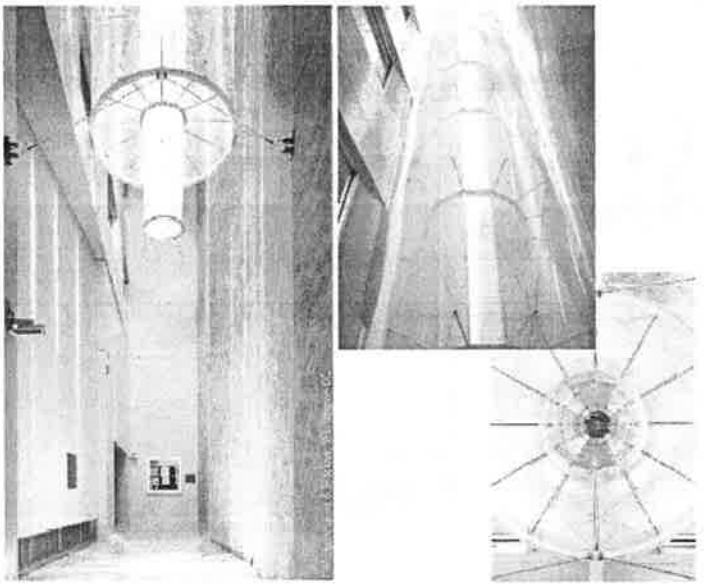




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Mirror reflect system





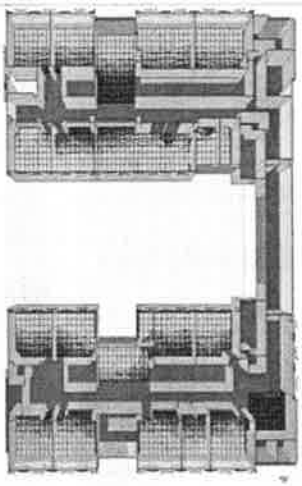
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Daylight Simulation – Base Case Scenario

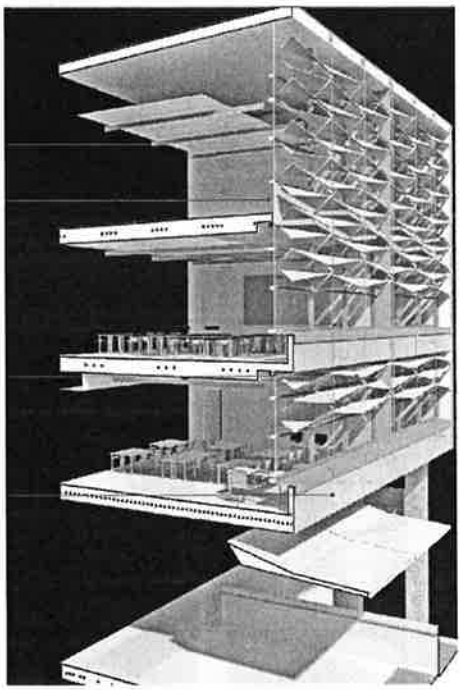
Result : Daylight Level
Daylight for LEED
Level 3 in Clear Sky
at 21st September 15:00



Lux level 269-5,382 lux is achieved at 83% of the regularly occupied space.

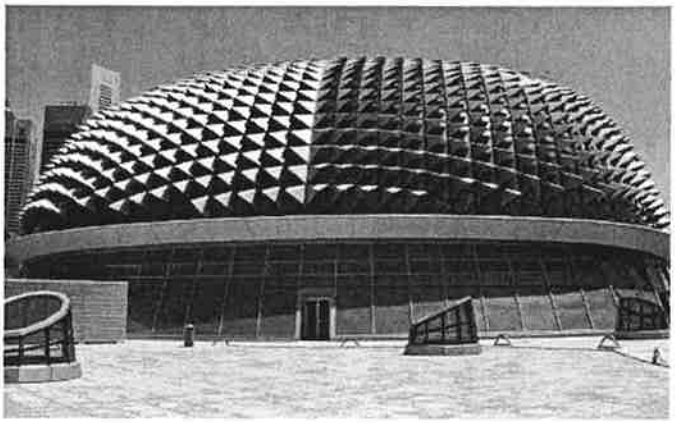


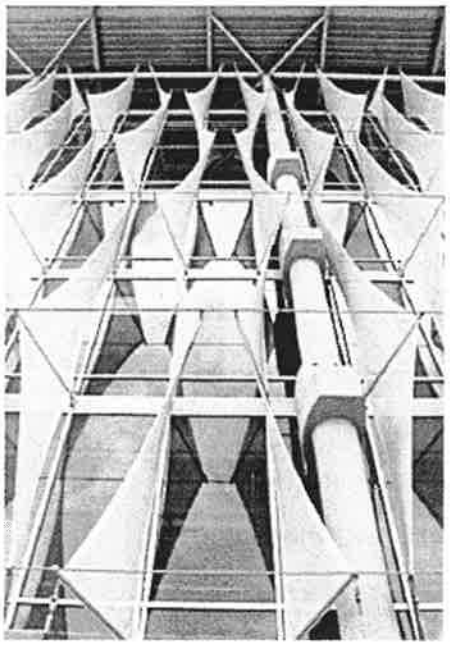




Daylighting

- Minimizing heat
  - Louver/façade screen
  - Sunshade

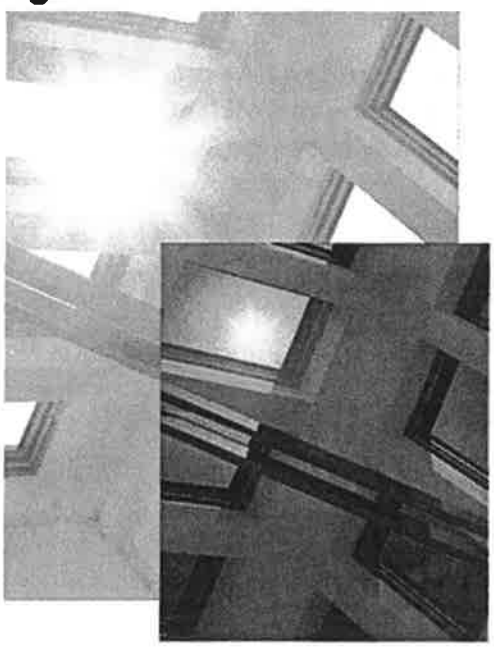




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Daylighting

- Minimizing heat
  - Thermochromic glass
  - Electrochromic glass



Glare

- Excessive glare is result of too intense daylight.
- As the eye attempts to even out the contrast between the task and the surrounding surfaces, the muscles of the eye have to work harder and more frequently.
- Particularly undesirable in computer work environments.

Varies considerably depending on

- *Orientation*
- *Presence of shading devices*
- *Other window properties*
- *Design conditions*

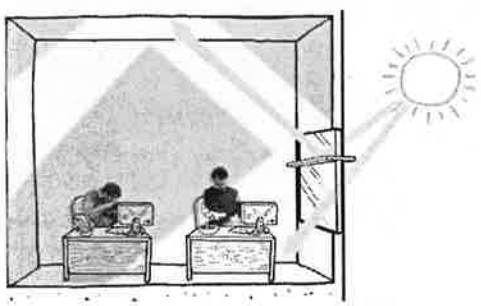


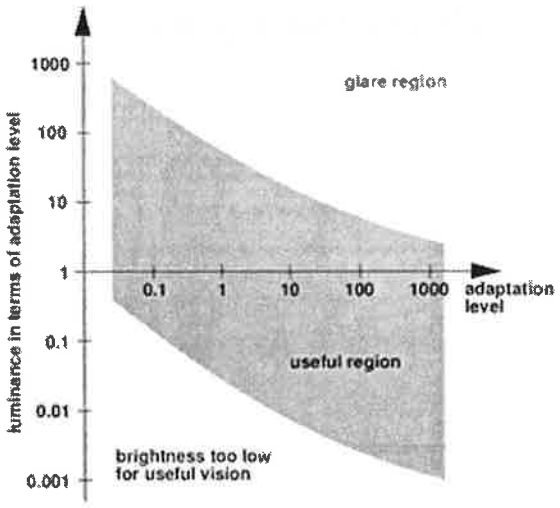




Effects of Glare

- Injures the eye
- Disturbs the nervous system
- Causes annoyance, discomfort & fatigue
- Reduces efficiency of work
- Interferes with clear vision
- Risk of accident increases





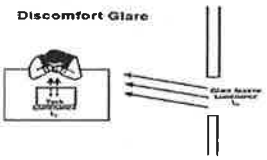
Glare Classification

Discomfort Glare

If the glare sources are not too bright, they are merely a nuisance and do not directly interfere with vision. This condition is called discomfort glare.

Disability Glare

If the luminance of the glare source is much higher, disability glare arises. This causes the adaptation level of the eye to increase resulting in in a reduced contrast of the object.





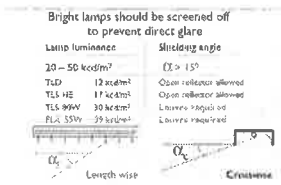
Direct glare

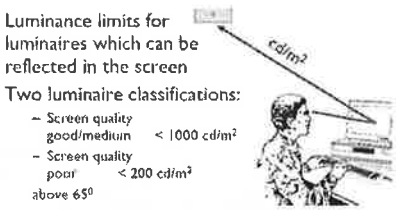
This is caused by light sources such as candles, artificial light fittings, or windows.

Indirect glare

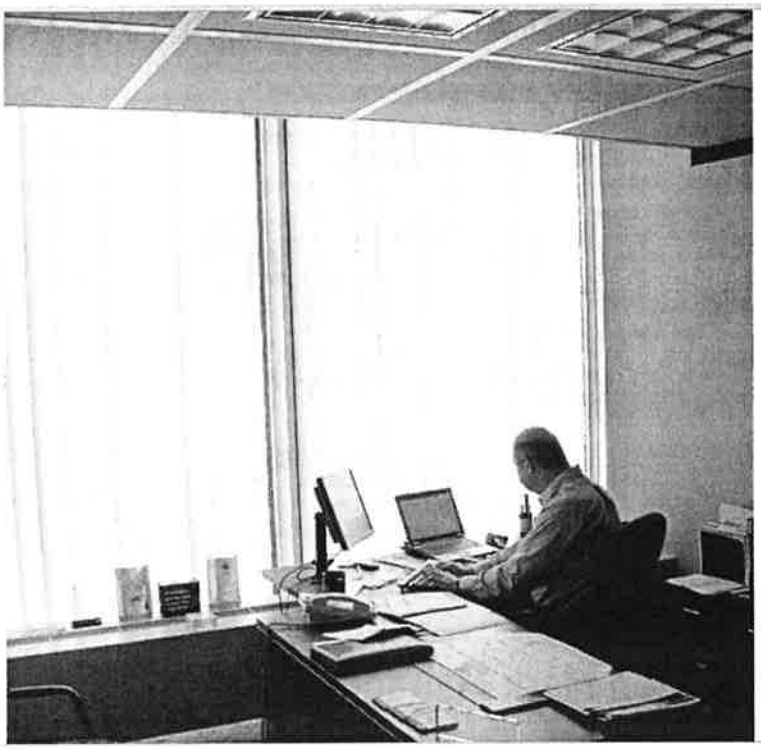
Even if the light source itself can not be seen by the observer, very reflective or glossy objects can cause bright splotches acting as indirect sources. In this case, a further differentiation may be made into











Daylighting

- Minimizing glare:
  - Curtains
  - Blinds
  - Lightshelves
  - Louvers
  - Translucent glass
  - Photochromic glass
  - Electrochromic glass



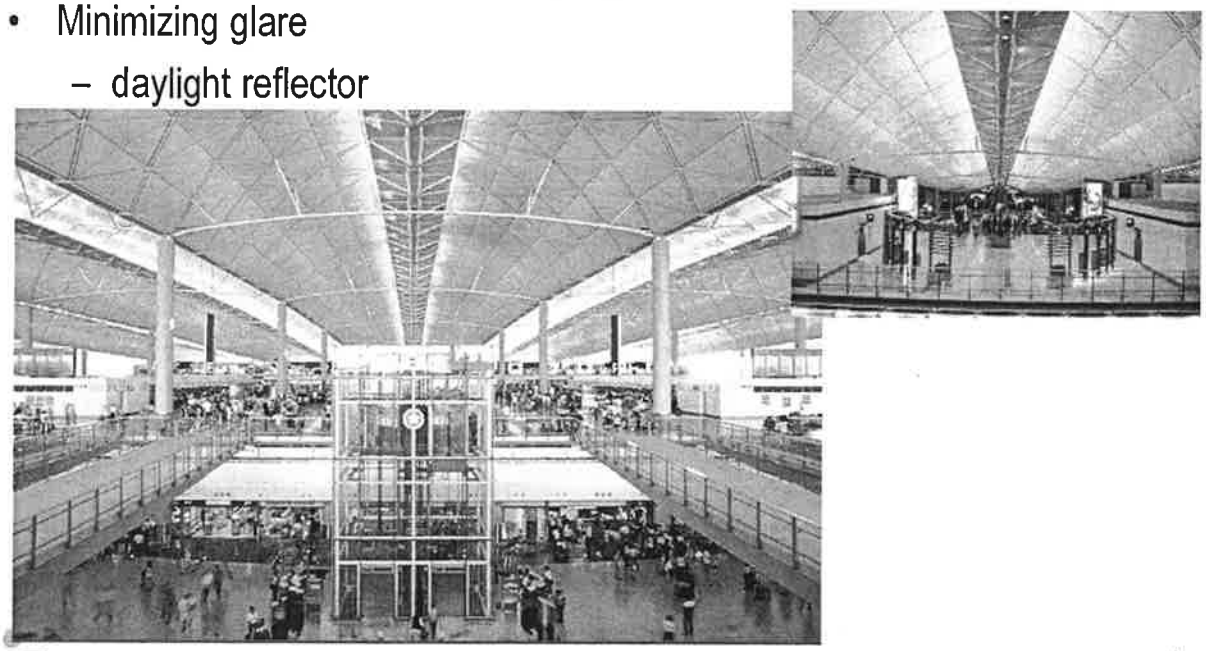


Direct sunlight can cause visual discomfort. Shutting the blinds here would eliminate the benefit of the daylight.

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Daylighting

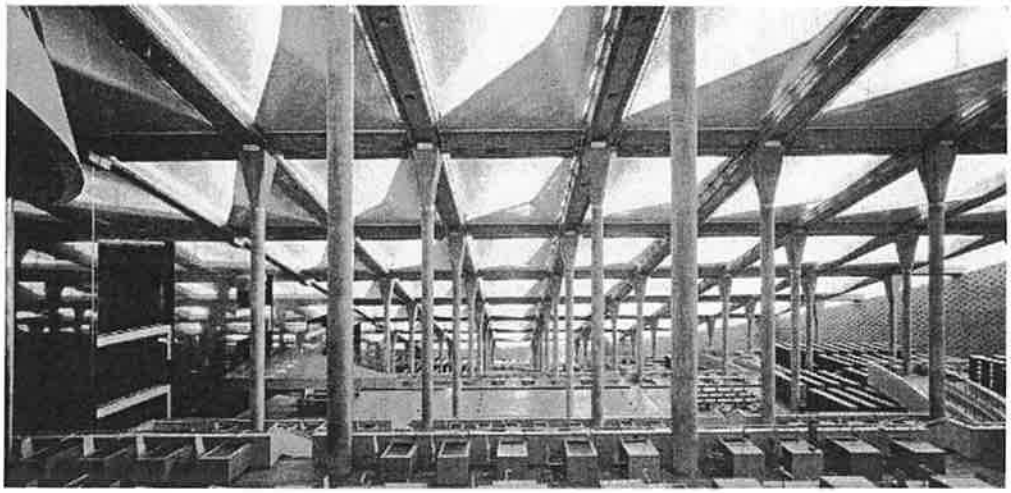
- Minimizing glare
  - daylight reflector



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Daylighting

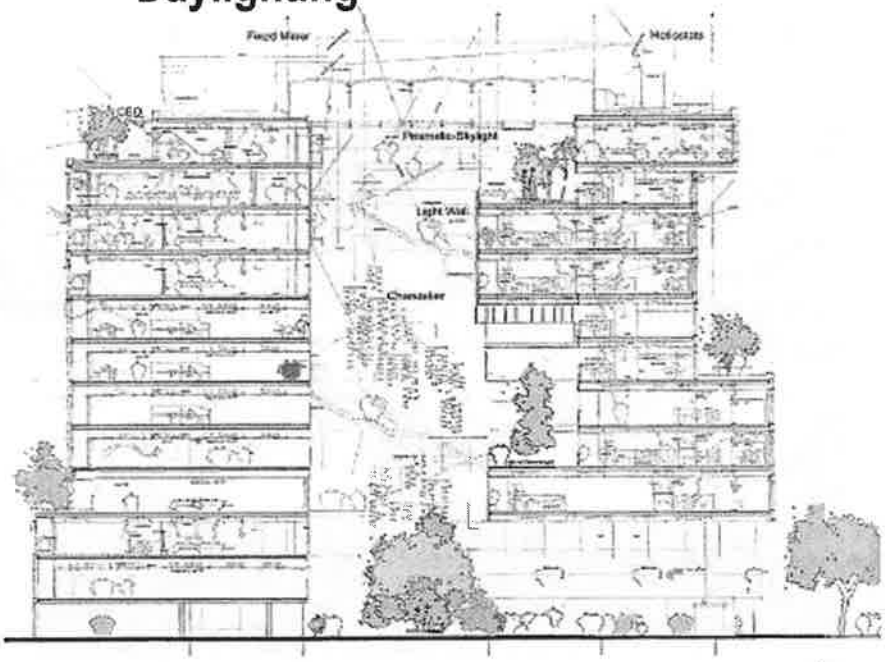
- Minimizing glare
  - Skylight allowing indirect daylight



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Daylighting

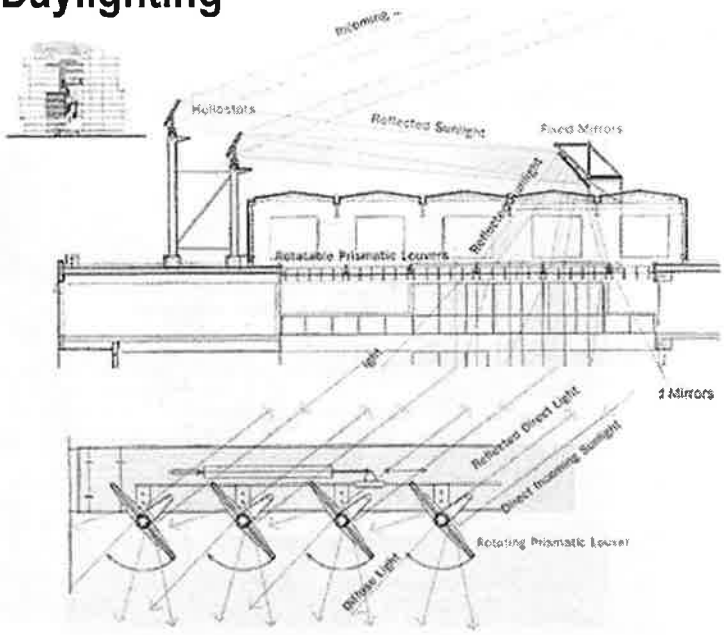
- Minimizing glare
  - Skylight allowing indirect daylight



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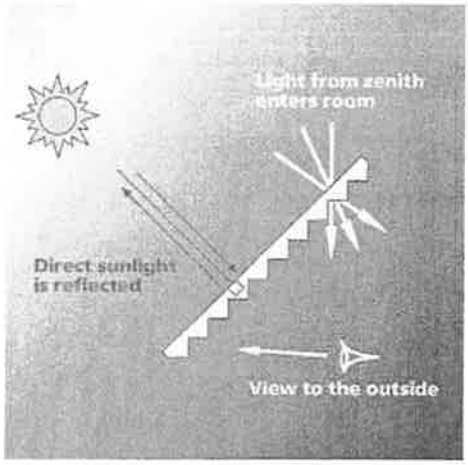
Daylighting

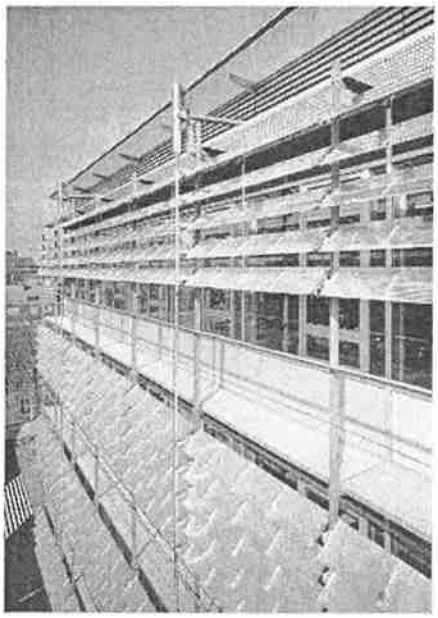
- Minimizing glare
  - Skylight allowing indirect daylight



Daylighting

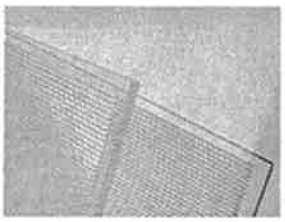
- Minimizing glare:
  - Prismatic panel

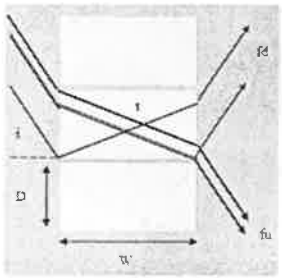




Daylighting

- Minimizing glare:
  - to redirect light to ceiling, for example : Laser cut panel



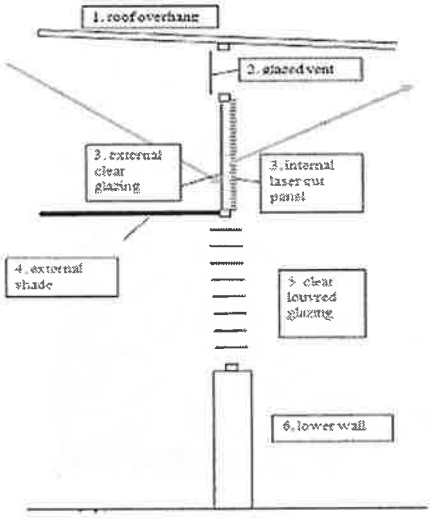




Daylighting

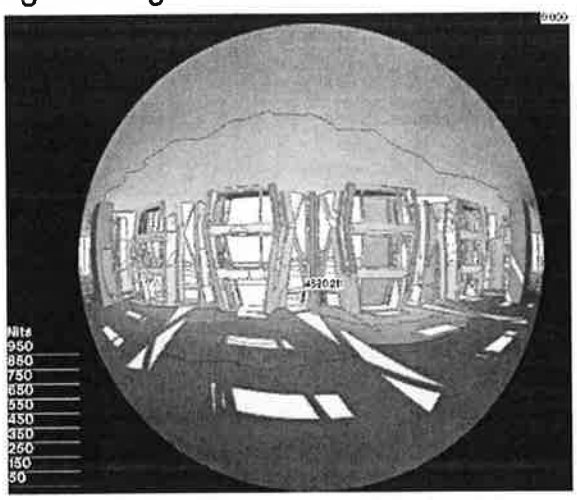
- Minimizing glare:
  - Laser cut panel

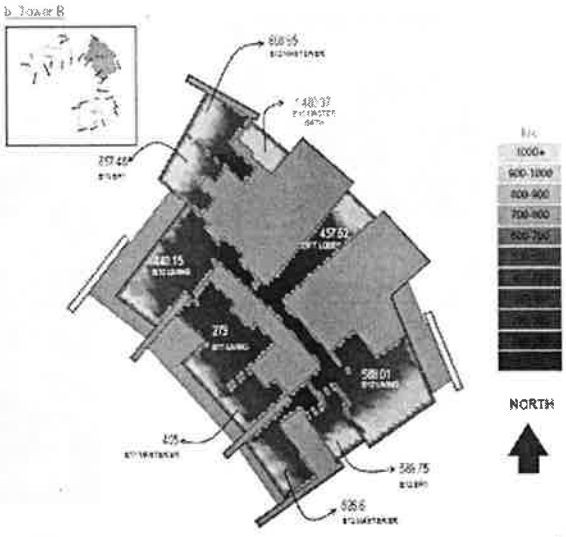




Daylighting

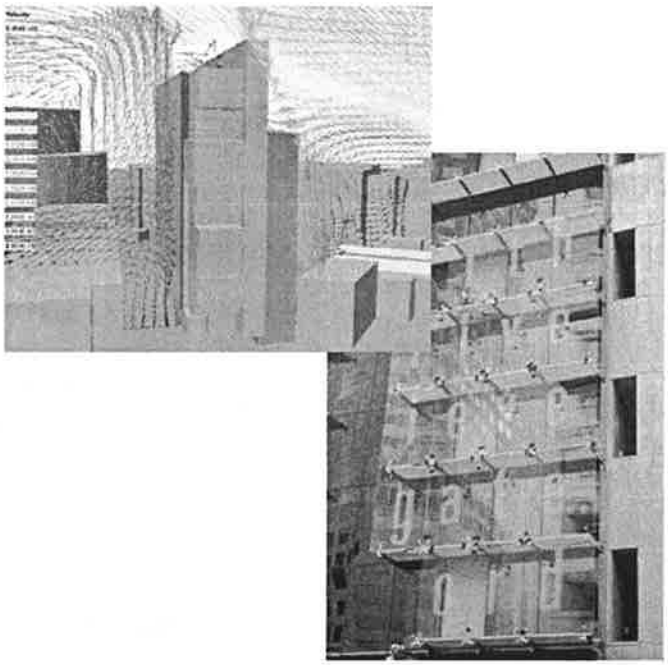
- Balancing Daylight amount and Glare
- Glare and daylight simulation to balance between sufficient amount of light and glare





Other Green Features

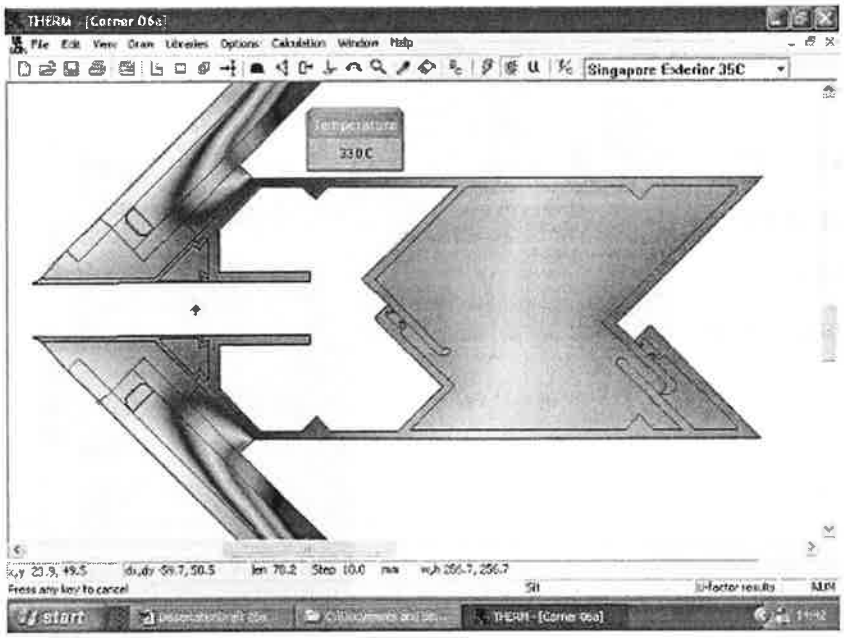
- **Energy Saving**
  - Green Wall
  - Double Skin / Cavity Walls
  - Thermally Broken facades
  - Water Cooled facades
  - Photovoltaic integrated facade
  - Cool paint
  - Operable louver

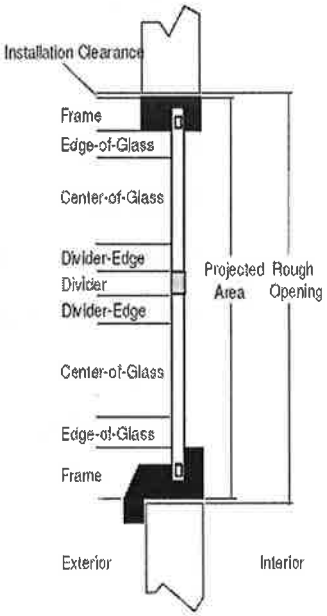


Other Green Features

- **Water Saving**
  - TiO2
  - Water collecting facades
- **Environmental Protection**
  - Recycled material
  - Green labeled paint or coating
- **Indoor Environment Quality**
  - Acoustics

Are we calculating heat transfer accurately?





References

- Goh, Thomas. (2001). BCA Seminar on Energy Efficiency in Building Design – Enhancing the Energy Standards. Building Management Department - BCA. Singapore.
- The Development & Building Control Division (P.W.D) Singapore. Handbook on Energy Conservation in Buildings and Building Services
- Commissioner of Building Control. (2004). Guidelines on Envelope Thermal Transfer Value for Buildings.
- en.wikipedia.org
- www.sq1.com
- www.healthy-house.co.uk
- Jodidio, Philip. (1997). Sir Norman Foster. Kolm : Benedikt Taschen Verlag GmbH
- Dobney, Stephen. (1997). The Master Architect Series II : Norman Foster. Victoria: The Images Publishing Group Pty Ltd
- www.lightingdesignlab.com
- http://www.csdesign.epsa.uq.edu.au
- www.solartran.com.au

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6. EXERCISE

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Exercise question

WWR

- 1. On the North façade, the building envelope only consists of window, concrete and aluminium cladding.

  window area is 2000m2; concrete area is 1000m2; aluminium cladding area is 1000m2

  what is WWR? $\frac{2000m^2}{4000m^2} = 0.5$

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Exercise question

Shading Coefficient of Fenestration

- 2. On the West façade, SC of glass is 0.7

  the length of horizontal sunshade is 1.1m

  the height of window below sunshade is 2.2m

  the sunshade is tilted 20°

  What is the total SC of fenestration system?

refer pg32: P = R1

table 11

SC1 = 0.7

P = 1.1m

H = 2.2m

SC2 = 0.655

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Exercise question

Total ETTV

- 3. ETTV of East façade is 70 W/m2. Its area is 4000m2

  ETTV of West façade is 60 W/m2.Its area is 4000m2

  ETTV of North façade is 40 W/m2.Its area is 8000m2

  ETTV of South façade is 30 W/m2.Its area is 8000m2

$$\frac{(70\times 4000)+(60\times 4000)+(40\times 8000)+(30\times 8000)}{4000+4000+8000+8000}$$

  What is the total ETTV of the building? 45w/m²