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The Application of the Three-phase Method in Evaluation of a Dynamic Shading Device

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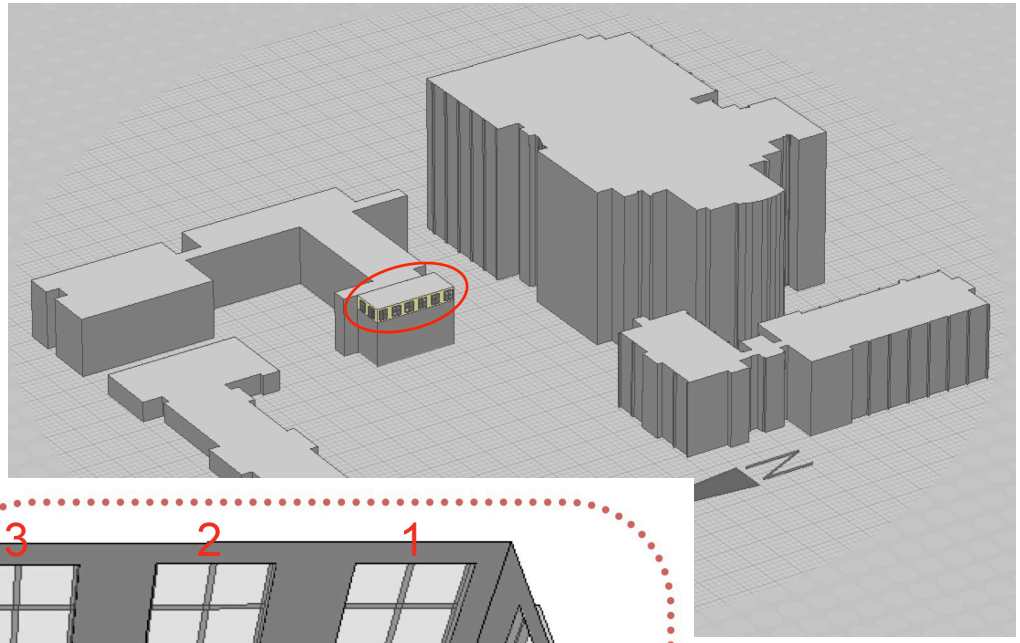
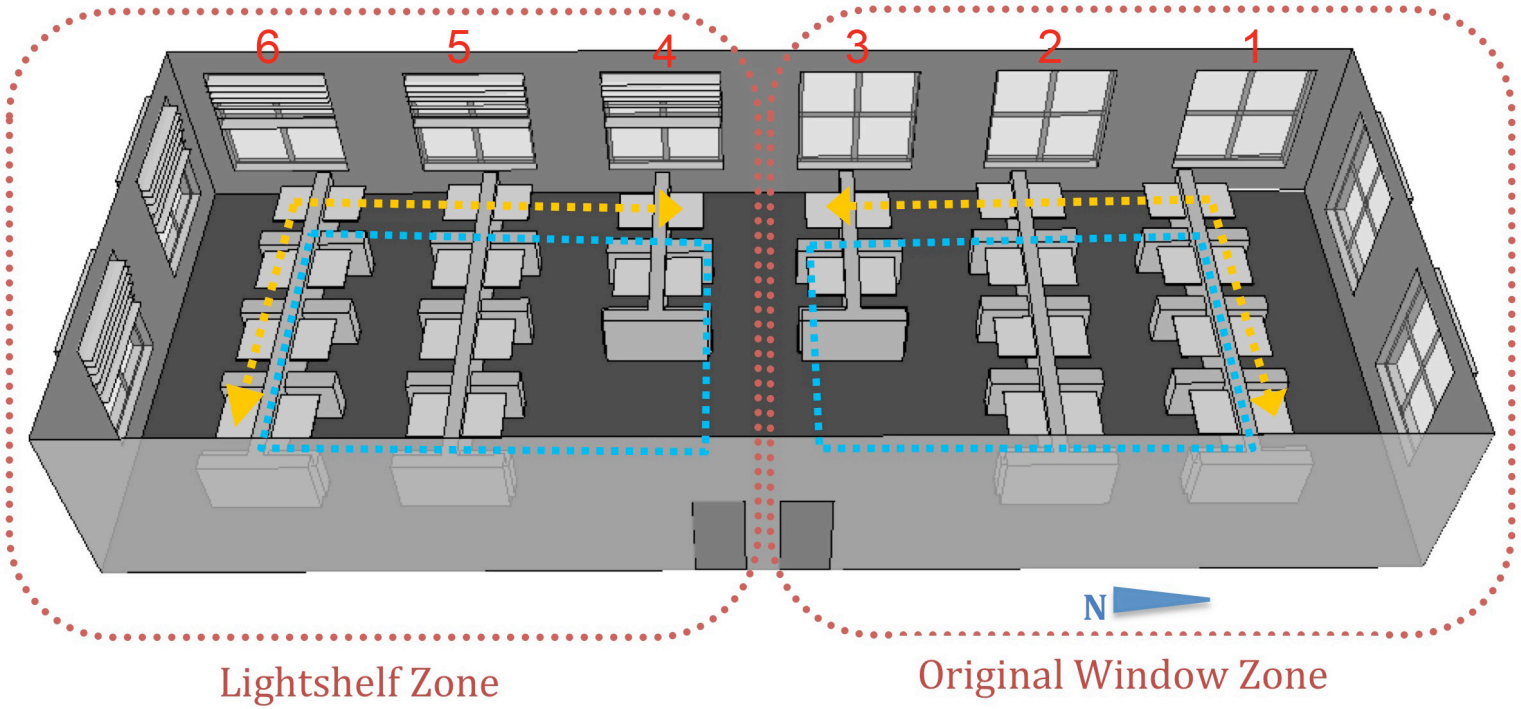
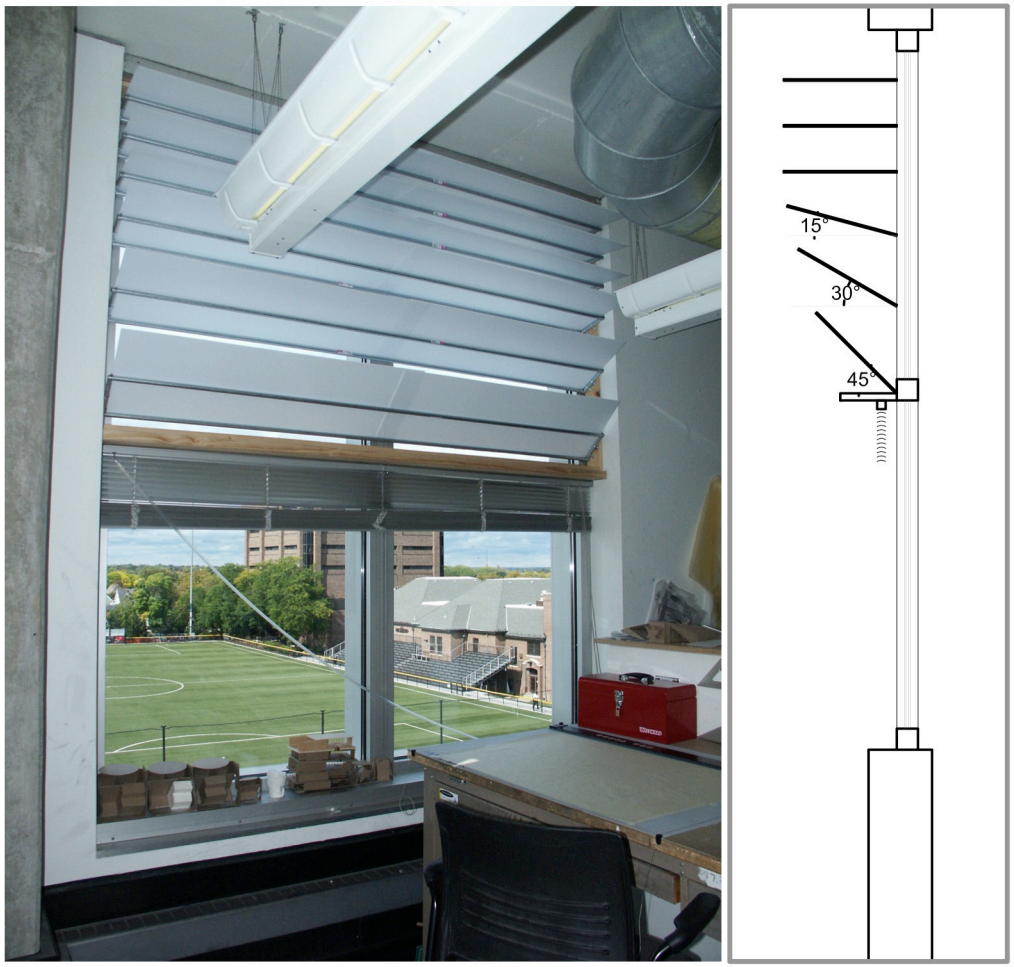
Background

Background





Background



Subdivided window design

Original window design

Background

Background

Table 1: The overall occlusion values calculated for west facing windows

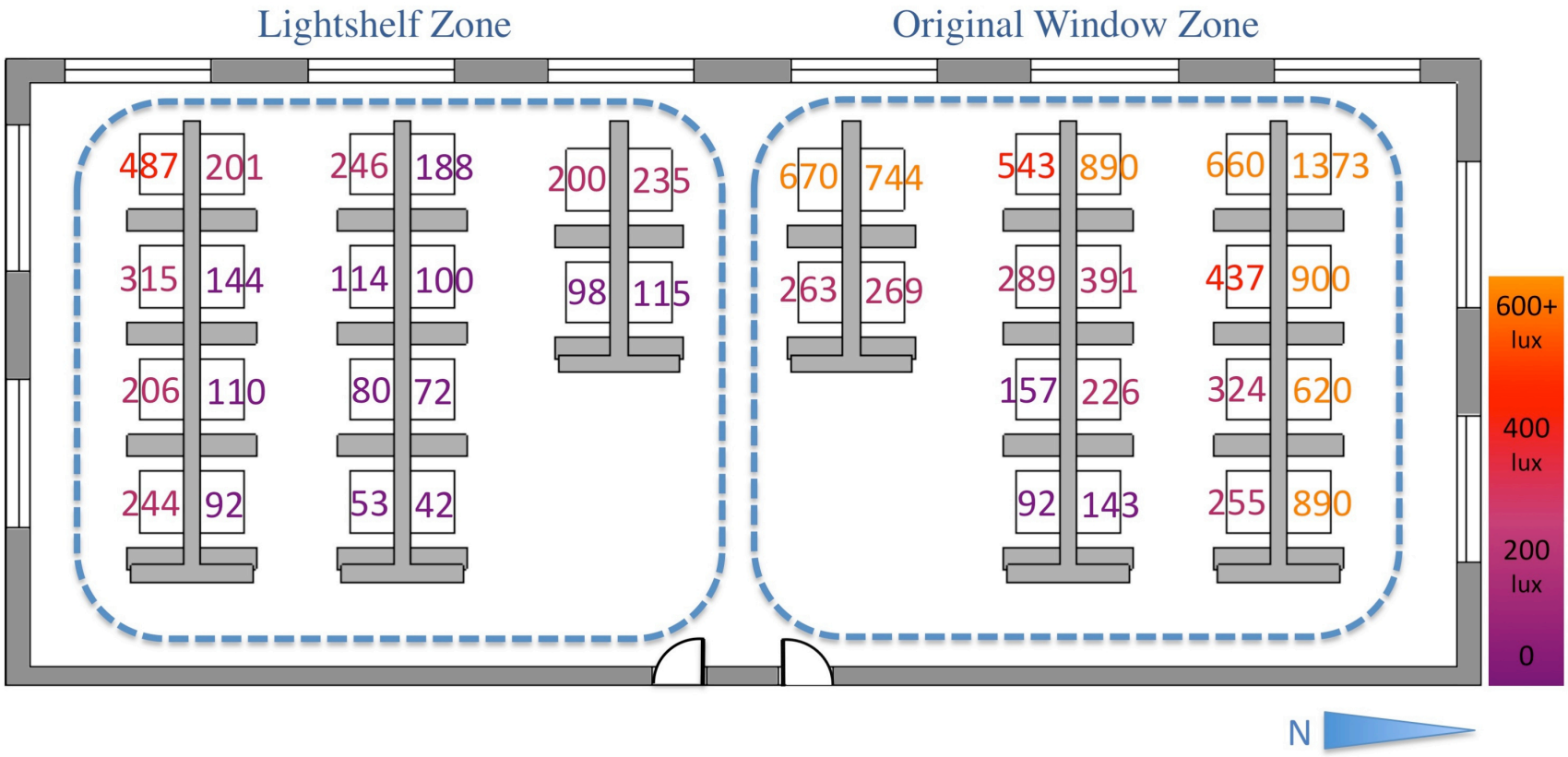
	Window Number	Overall Occlusion	Occlusion in the morning	Occlusion in the afternoon
Original Windows	Window 1	8%	0.0%	16.6%
	Window 2	70%	69.8%	69.4%
	Window 3	65%	65.7%	64.9%
Lightshelf Windows	Window 4	20%	20.2%	20.2%
	Window 5	25%	24.6%	24.6%
	Window 6	41%	33.9%	48.6%

Background

Table 2: Summary of lighting energy use from Feb 23 to May 16, 9am to 5pm.

Luminaries location	Number of the hours the lights were turned on between 9 am and 5 pm	Percent of the time the lights were turned on between 9 am and 5 pm
Lightshelf zone – Perimeter	298 h	44%
Lightshelf zone - Core	326 h	48%
Original window zone –Perimeter	478 h	71%
Original window zone – Core	491 h	73%

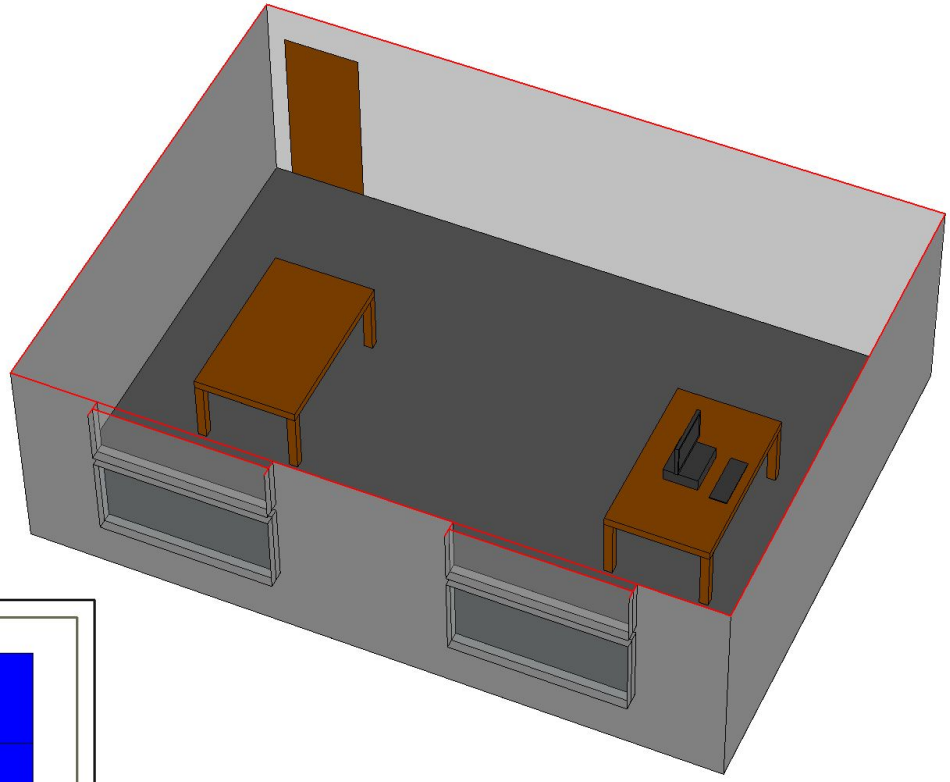
Background

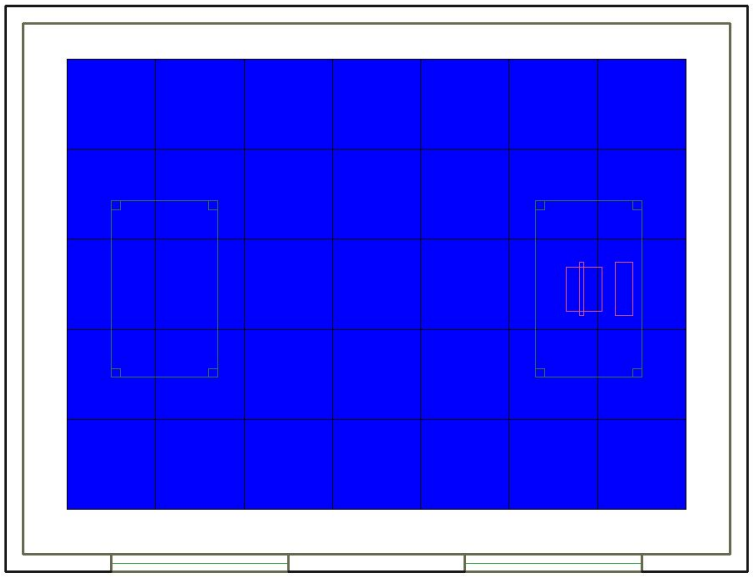

Lightshelf Zone
Original Window Zone
487 201
315 144
206 110
244 92
246 188
114 100
80 72
53 42
200 235
98 115
670 744
263 269
543 890
289 391
157 226
92 143
660 1373
437 900
324 620
255 890
600+ lux
400 lux
200 lux
0
N

The Three-phase Method

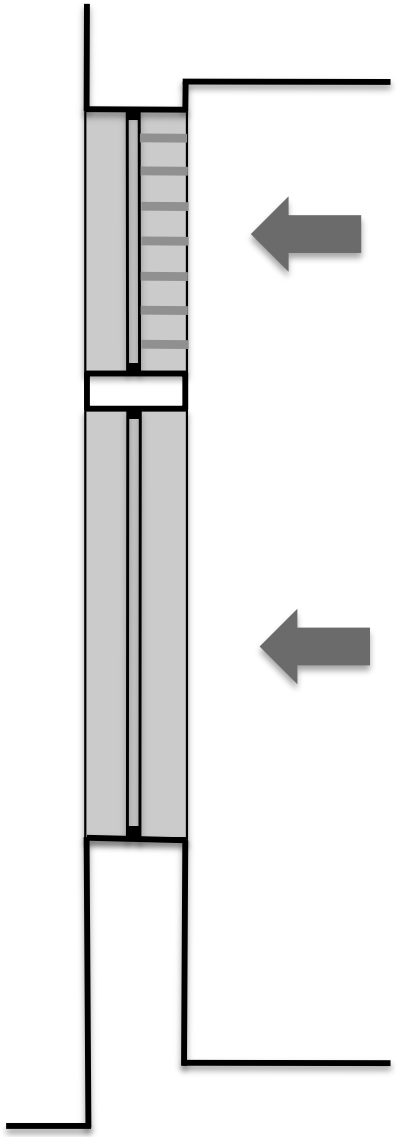
- View Matrix
- Transmission Matrix (BSDF)
- Daylight Matrix
- Sky Matrix, Sky Vector
- dctimestep

View Matrix





Transmission Matrix



- Liquid Crystal Louver
- Electrochromic Louver
- Electrochromic Glass
- White Opaque Louver

- Venetian blinds at 80
- No blinds

Transmission Matrix

Shade Material

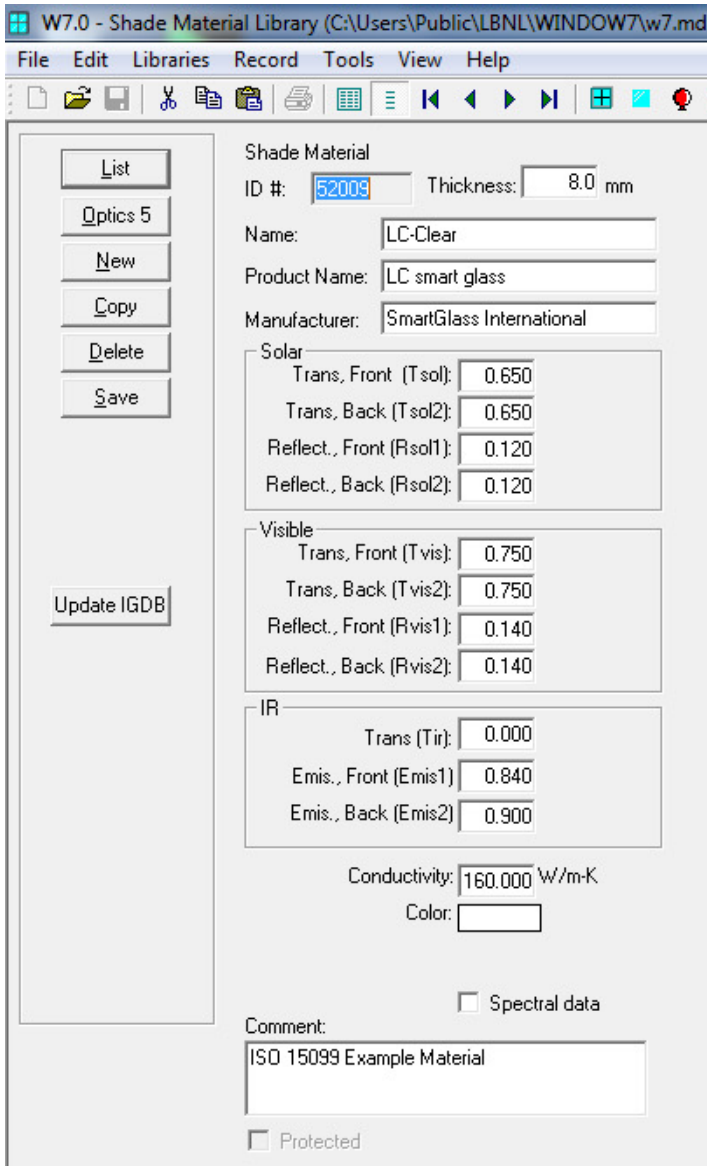
LC-clear

LC-hazed

EC-bleached

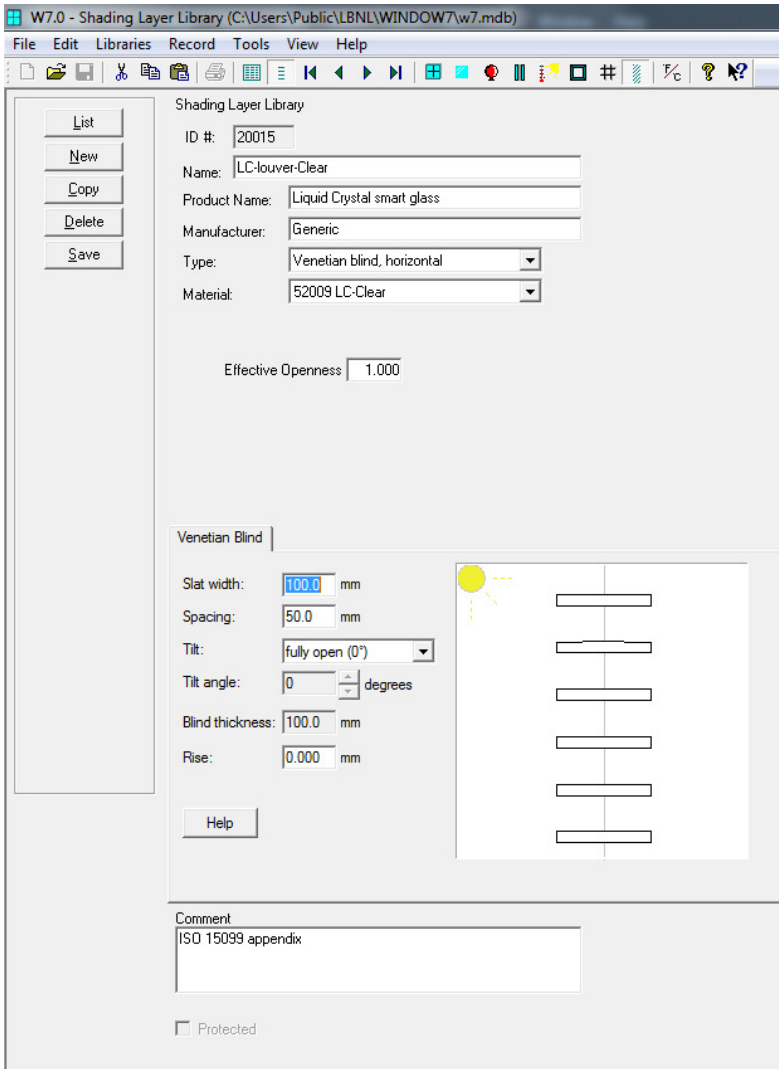
EC-tinted

Slat metal A



Transmission Matrix

Shade Material	Shading Layer
LC-clear	LC louver-clear
LC-hazed	LC louver-hazed
EC-bleached	EC louver-bleached
EC-tinted	EC louver- tinted
Slat metal A	EC glass-bleached
	EC glass-tinted
	Opaque louvers
	Venetian 80

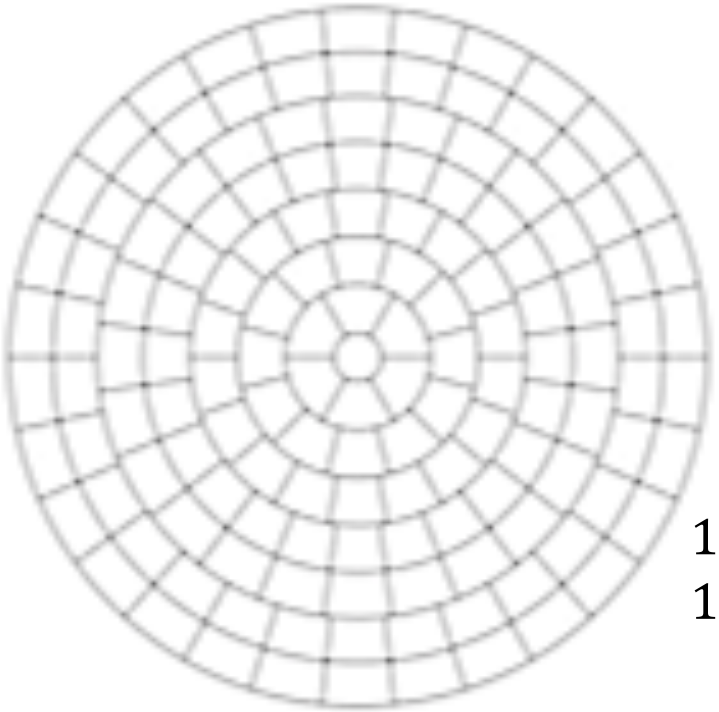


Transmission Matrix

Shade Material	Shading Layer	Glazing System
LC-clear	LC louver-clear	Low-e+ClearLC_louver
LC-hazed	LC louver-hazed	Low-e+HazedLC_louver
EC-bleached	EC louver-bleached	Low-e+BleacheEC_louver
EC-tinted	EC louver- tinted	Low-e+TintedEC_louver
Slat metal A	EC glass-bleached	Low-e+BleacheEC_glass
	EC glass-tinted	Low-e+TintedEC_glass
	Opaque louvers	Low-e+Opaque_louver
	Venetian 80	Low-e+Venetian 80
		Low-e

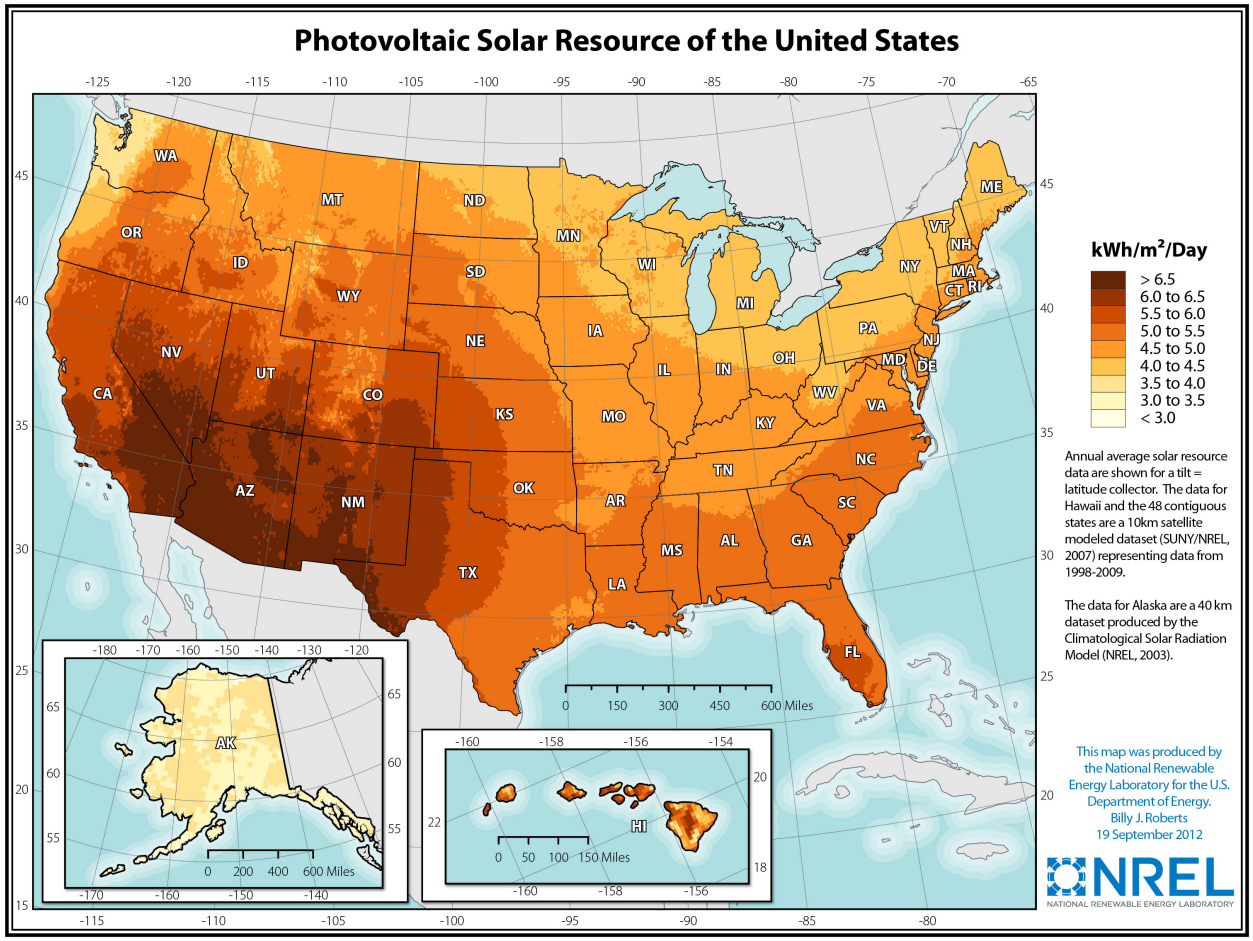
Daylight Matrix

- Windows.dmx
- Clerestories.dmx



145 Klems Divisions
1000 sample rays per division

Sky Matrix and Sky Vector



Sky Matrix:

Seattle
Milwaukee
San Francisco
Dallas
Phoenix

Sky Vector:

Summer Solstice,
Winter Solstice,
Equinox,
at 10, 12, 14, 16 (sunny)
Cloudy Equinox noon

DCTIMESTEP

photocells_W.vmx — Windows.dmx — Venetian80.xml, Low-e.xml — Seattle.smx, Milwaukee.smx, SanFrancisco.smx, Dallas.smx, Phoenix.smx

photocells_C.vmx — Clerestories.dmx — ClearLC_louver.xml, HazedLC_louver.xml, BleachedEC_louver.xml, TintedEC_louver.xml, BleachedEC_glass.xml, TintedEC_glass.xml, Opaque_louver.xml — Seattle.smx, Milwaukee.smx, SanFrancisco.smx, Dallas.smx, Phoenix.smx

Data Analysis

In the spreadsheet:

1- The RGB values were converted into Illuminance.

2- Transmitted vertical irradiance was calculated from the date, time, latitude, direct normal and diffuse horizontal irradiance data in each timestep.

3- Data was filtered by occupancy (8 A.M to 5 P.M.)

4- Control algorithm was set as follows:
If $\mathbf{I_{Transmitted\ vertical} > 50\ W/m^2}$, venetian blinds are closed.
If $\mathbf{I_{Direct\ normal} > 0.05 * I_{Diffuse\ horizontal}}$, switchable materials are tinted/hazed.

5- Dynamic Daylight Metric was calculated for each shading system.

Illuminance Results

Table 3: Average UDI(200-2000) in the Room

	Liquid Crystal Louvers UDI (200-2000)	Elechtrochromic Louvers UDI (200-2000)	Elechtrochromic Glass UDI (200-2000)	Opaque Louvers UDI (200-2000)
Dallas	63.78%	28.27%	25.42%	50.29%
Milwaukee	59.47%	23.51%	19.17%	47.98%
Phoenix	70.37%	33.92%	26.94%	59.66%
San Francisco	66.32%	32.54%	24.11%	56.11%
Seattle	52.98%	25.93%	19.81%	44.93%

DCTIMESTEP

W_%03d.hdr — Windows.dmx

- Venetian80.xml
- Low-e.xml

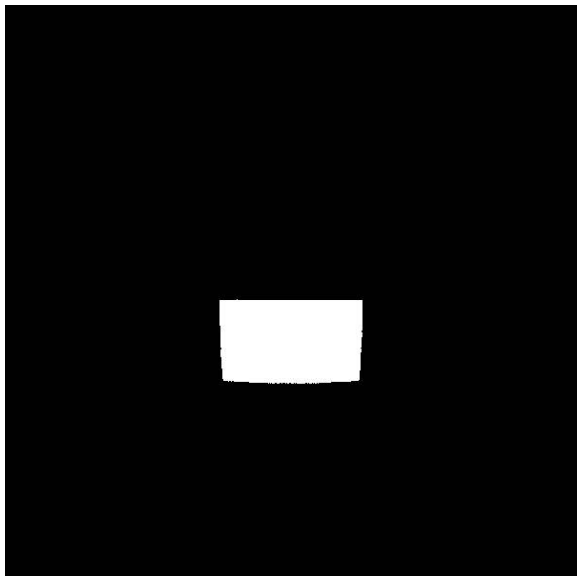
- 6-21_10.skv
- 6-21_12.skv
- 6-21_14.skv
- .
- .
- .
- cloudy

C_%03d.hdr — Clerestories.dmx

- ClearLC_louver.xml
- HazedLC_louver.xml
- BleachedEC_louver.xml
- TintedEC_louver.xml
- BleachedEC_glass.xml
- TintedEC_glass.xml
- Opaque_louver.xml

- 6-21_10.skv
- 6-21_12.skv
- 6-21_14.skv
- .
- .
- .
- cloudy

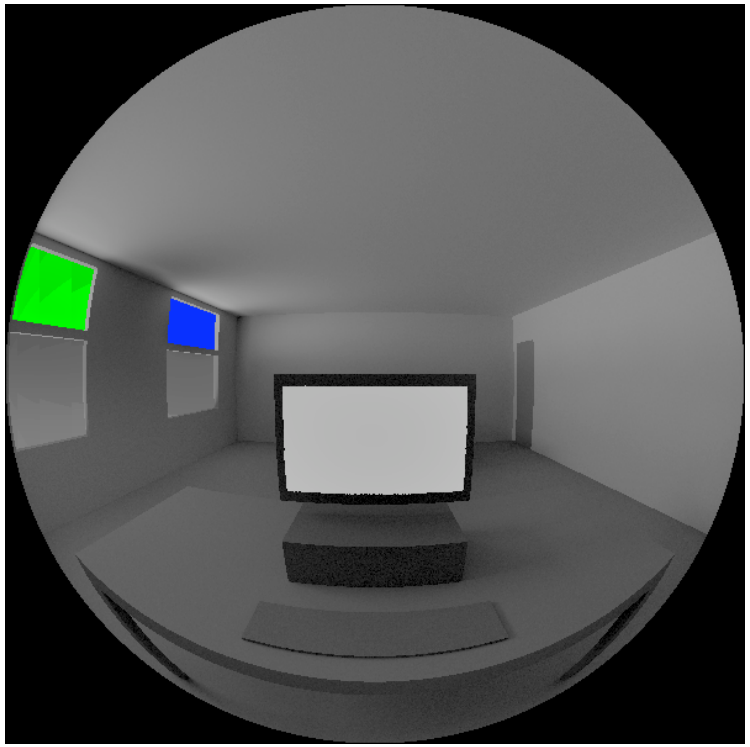
DCTIMESTEP

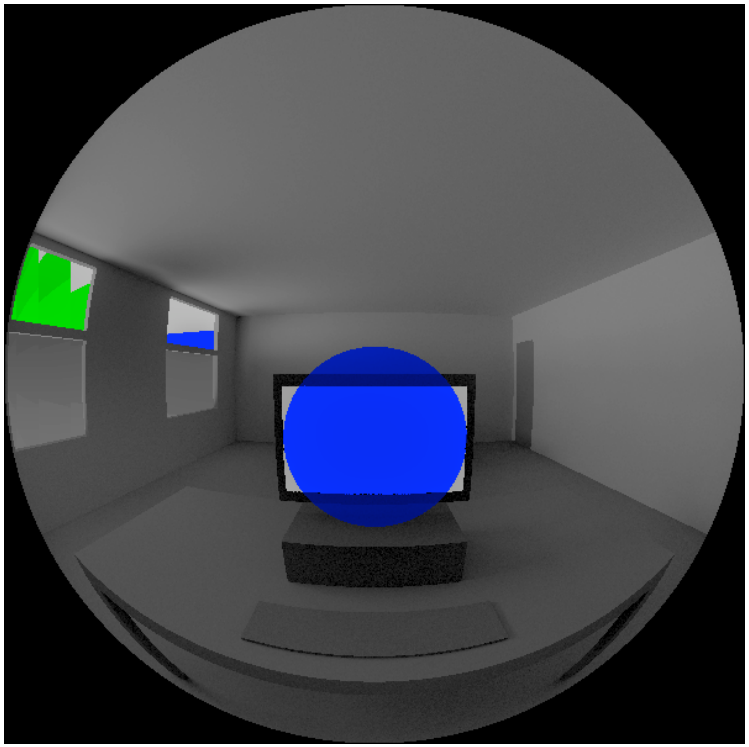

Venetian 80 and Hazed LC,
6/21 at 2 P.M., sunny sky

Glare Results

Glare metrics calculated for Venetian 80 and Hazed LC on 6/21 at 2 P.M., sunny sky



DGP_{7x}= 0.111
DGI_{7x}= 13.732
UGR_{7x}= 16.521



$DGP_{4x\ task}$= 0.112
$DGI_{4x\ task}$= 13.975
$UGR_{4x\ task}$= 16.709

Glare Results

Table 4: Average Glare Sensation Levels

	7 times Scene Average Threshold			4 Times Task Average Threshold		
	DGP	**DGI**	**UGR**	**DGP**	**DGI**	**UGR**
Hazed LC	0.182	16.596	20.626	0.182	16.658	20.681
Opaque louver	0.156	14.778	18.472	0.157	14.997	18.655
Tinted EC- Glass	0.024	16.359	19.949	0.020	-	-
Tinted EC-Louver	0.110	14.186	17.812	0.111	14.373	17.953
Clear LC	0.165	14.591	17.602	0.154	9.289	13.291
Bleached EC-Glass	0.176	14.619	17.705	0.168	11.758	14.978
Bleached EC-Louver	0.161	14.452	17.439	0.150	9.190	13.159

References

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Thank You