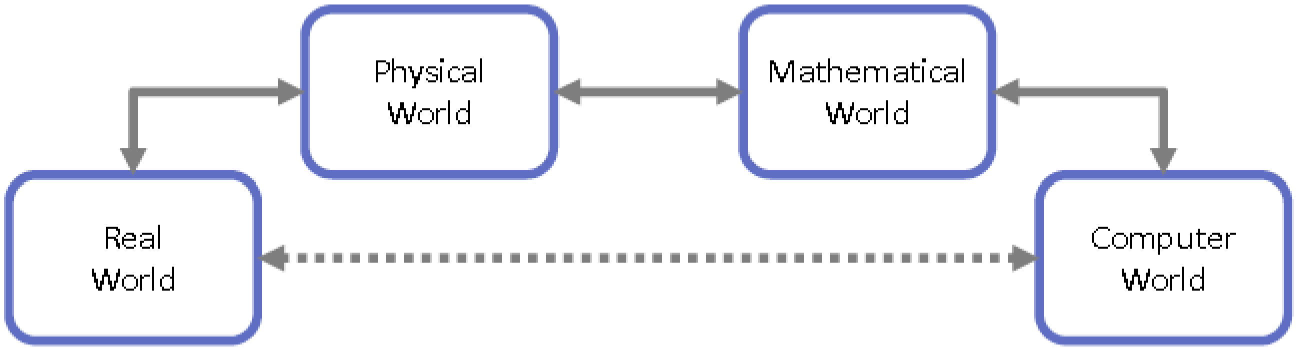
SF ASHRAE – Façade Simulation

October 8, 2014

Introduction
What exactly is simulation?

Building Performance simulation models and observes a building's behavior under a specific usage scenario…



A model can reveal behaviors that contribute to the performance under study.

The better the design of the experiment, the better the signal

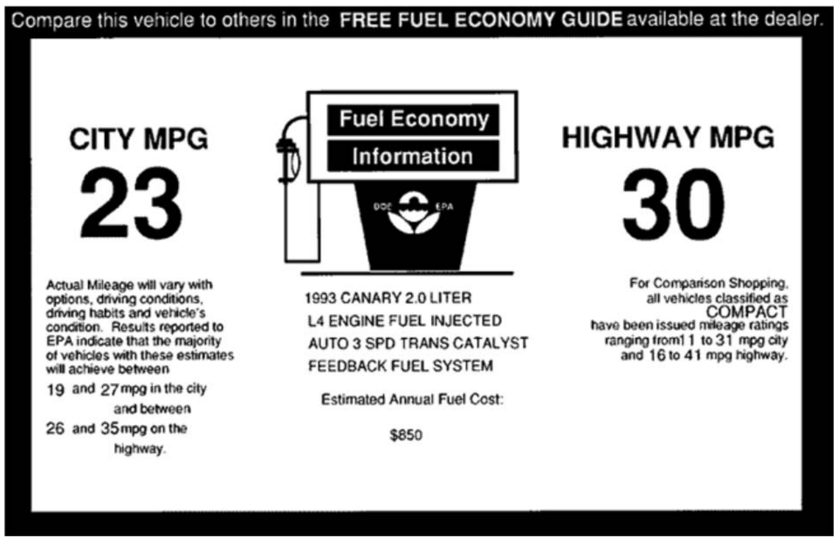
also know as

Garbage in … Garbage Out

Introduction
What exactly is simulation?

Energy Modeling predicts actual energy utilization.*

*accounting for the idealized test environment and the actual use and condition of the building.



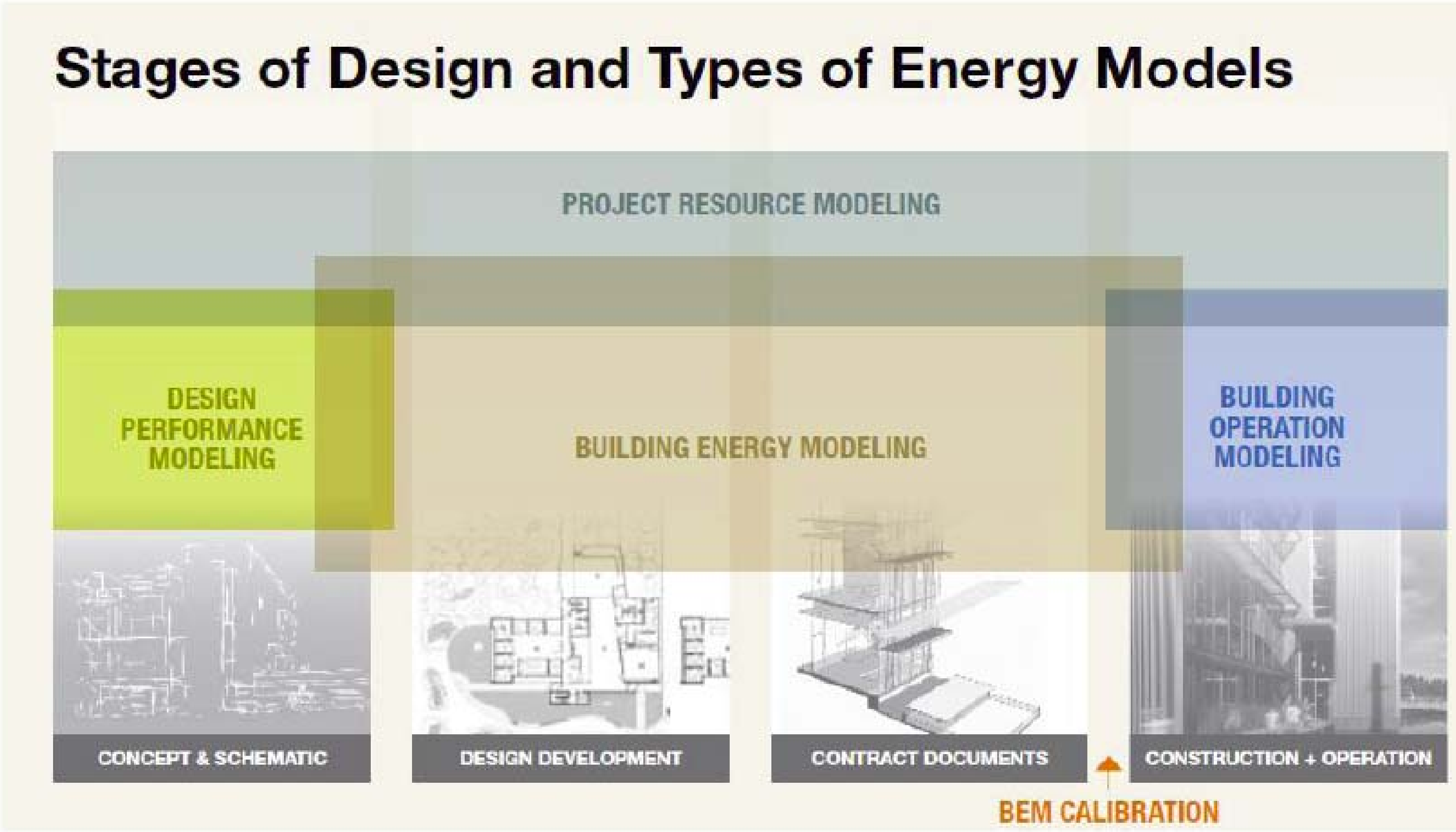
The primary objective of Energy Modeling is to inform the decision-making process while recognizing trade-offs between different criteria.

…this is ½ right…

Modeling is also a useful predictive tool if the modeler addresses the differences between Model World and the Real World.

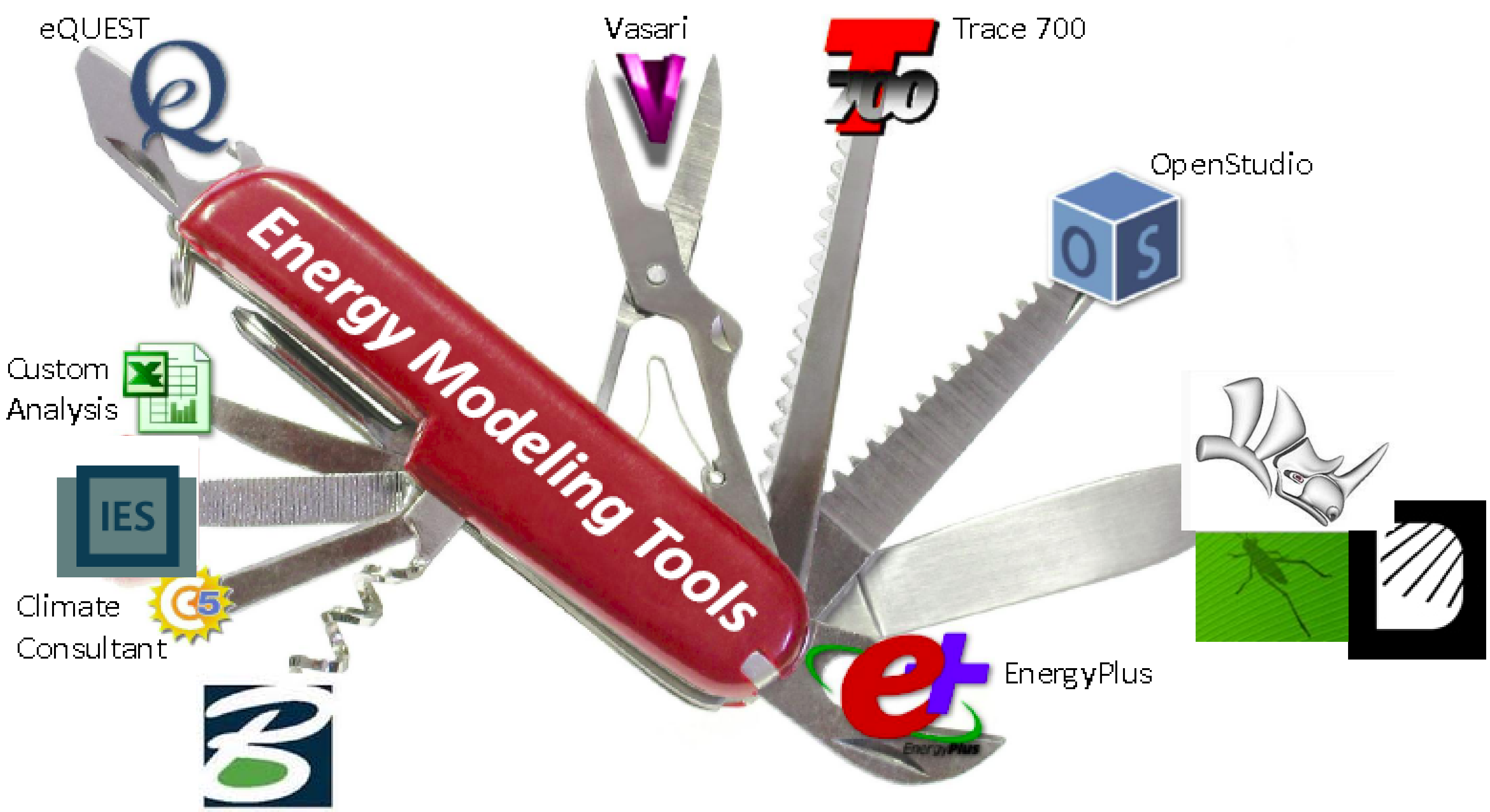
We will not get to carbon neutrality without improving the ability to use models as a reliable predictive tool.

Introduction
Different Types of Simulation



From AIA, "An Architect's Guide to Integrating Energy Modeling In The Design Process," 2012

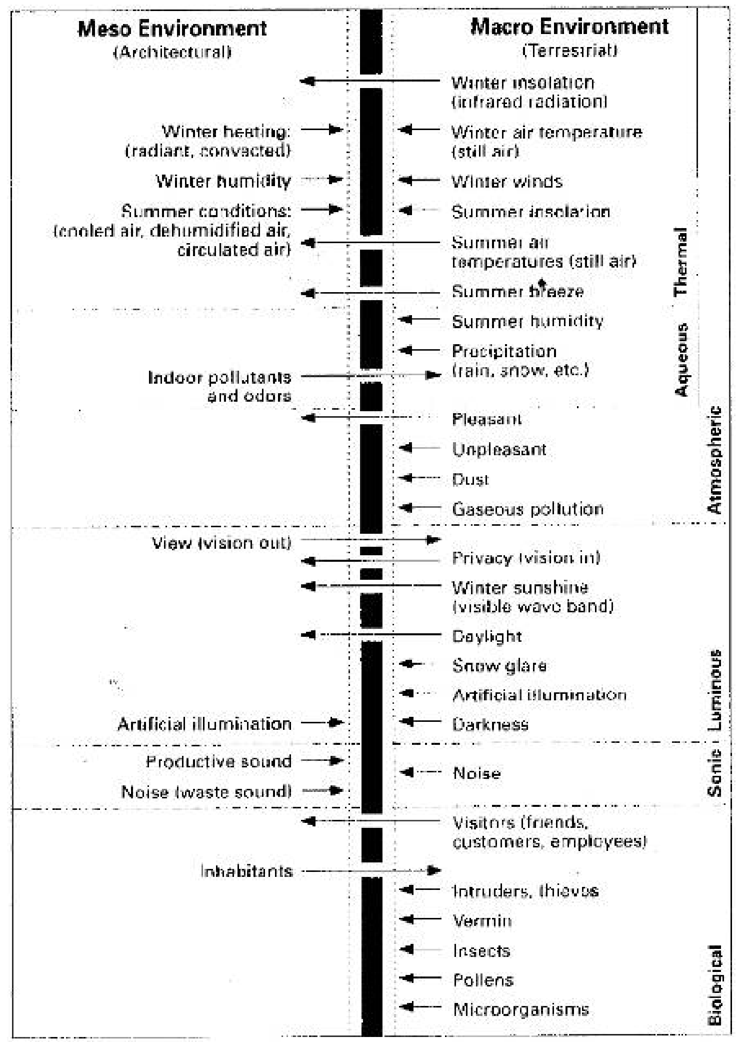
Simulation Tools
What tools can I use?



Key Issues for Envelopes

Building envelopes: a lot happens in a few inches!

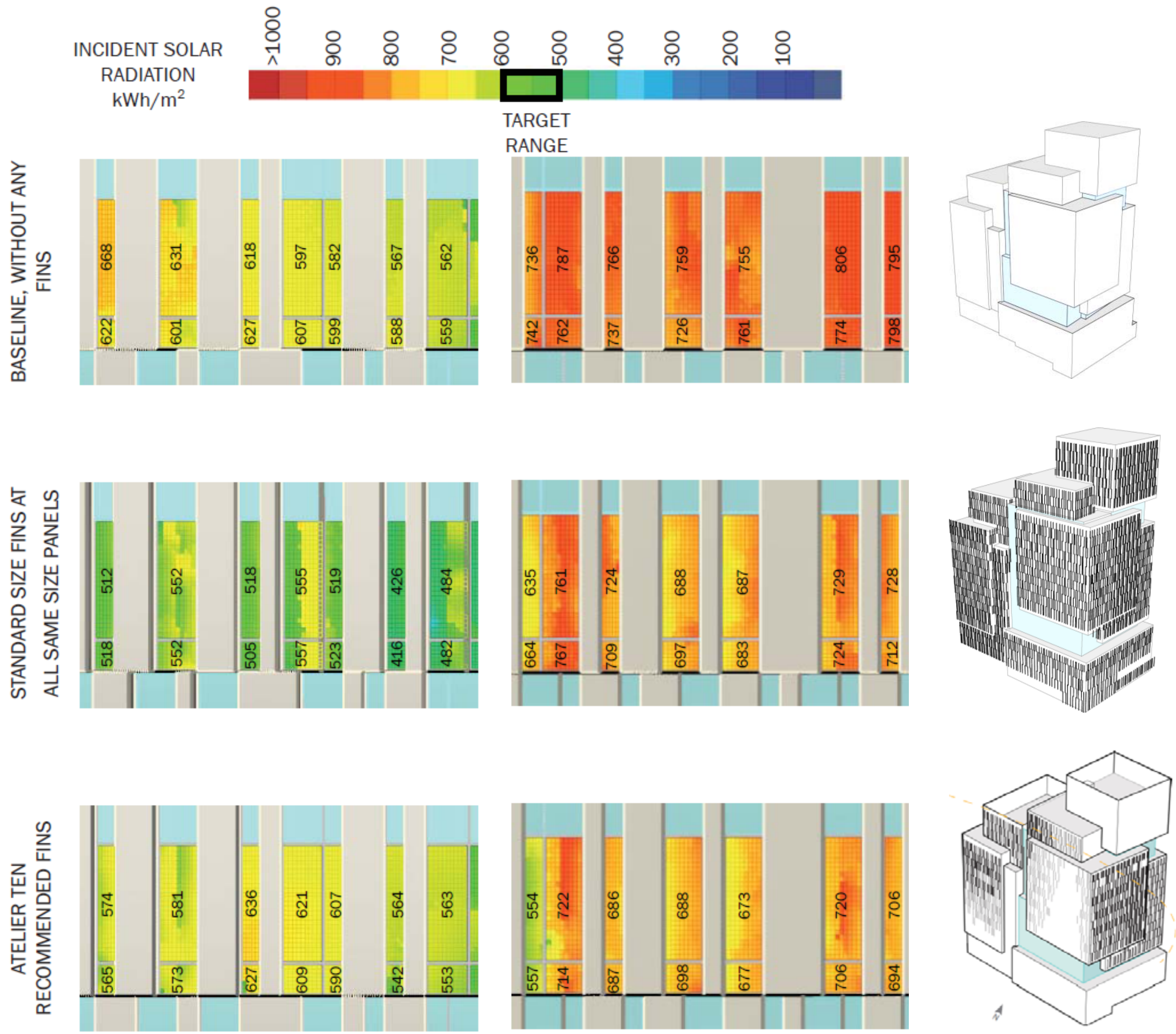
- Conductive heat gain
- Conductive heat loss
- Solar heat gain
- Thermal comfort adjacent to envelope
- Daylight access & distribution
- Glare control
- Condensation & waterproofing
- Natural ventilation
- Infiltration
- Sustainable materials
- Views
- Acoustics
- Structure
- Building expression



Façade Drivers

- Peak Solar Gain – Reduce peak solar loads to reduce air change rates and first cost of HVAC equipment; improve thermal comfort in spaces adjacent to facades
- Daylight Quality & Visual Comfort – Reduce glare from low angle sun to improve occupant comfort; create evenly daylight spaces that avoid contrast
- Daylight Quantity – Reduce electric lighting energy use by daylighting perimeter spaces
- Annual Solar Gain – Solar radiation can drive both heating and cooling loads throughout the year and must be properly accounted for in the design of any building. The management of solar radiation has a direct effect on annual energy use.
- Thermal Comfort –The façade has a direct impact on occupant thermal comfort that must be managed.

External Shading Studies



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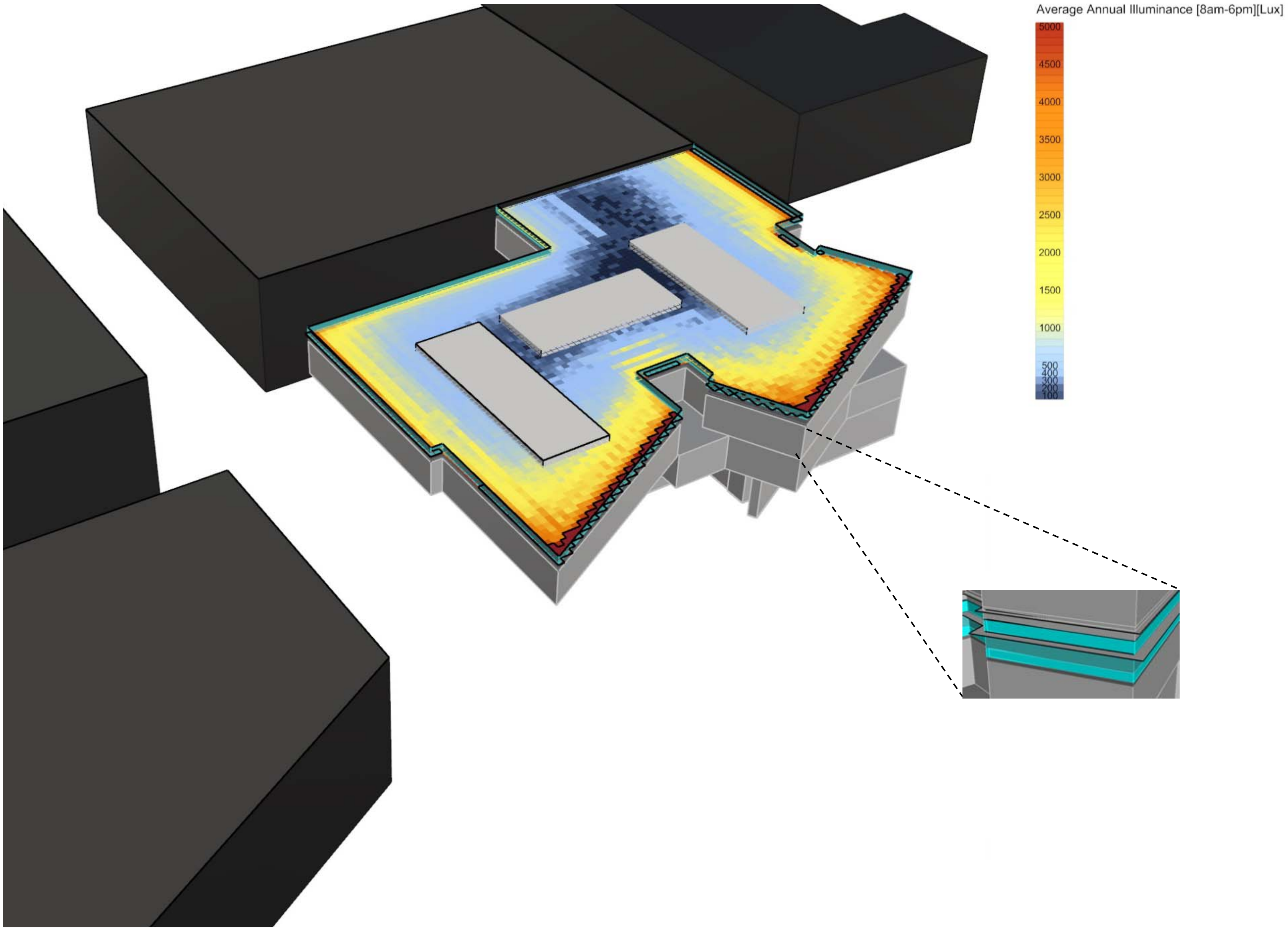
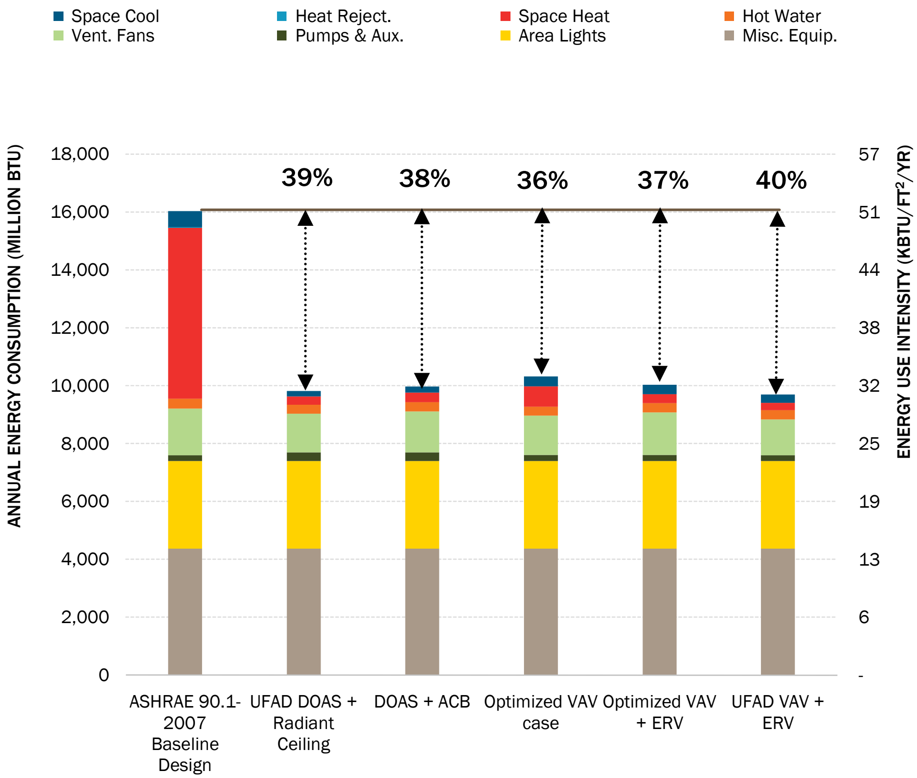
Daylighting



Energy Efficiency

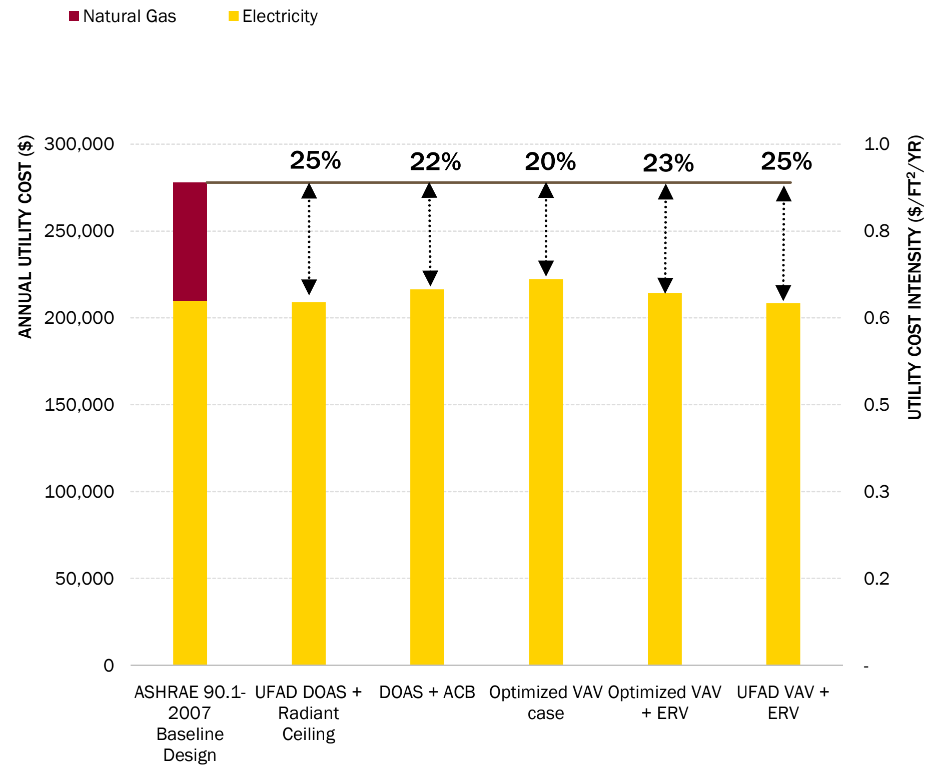
ANNUAL SITE ENERGY CONSUMPTION

7159 NIKE HQ (OFFICE BUILDING)



ANNUAL UTILITY COST

7159 NIKE HQ (OFFICE BUILDING)



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Thermal Comfort

ATRIUM FLOOR TEMPERATURE AT A SINGLE POINT IN TIME IN SUMMER (JUNE 1ST, 1PM)

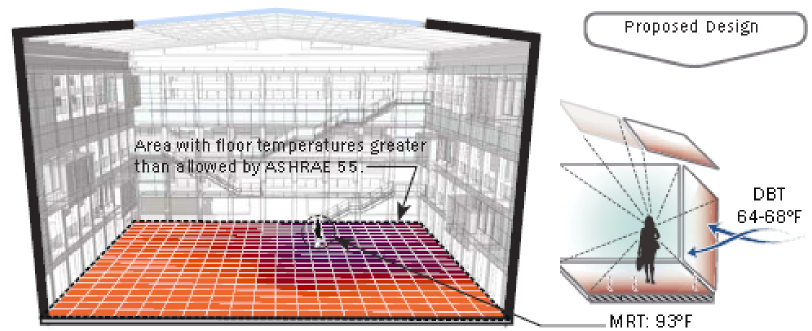


FIGURE 3: OPTION 1 - PROPOSED DESIGN FLOOR TEMPERATURE [SHGC: 0.38][4" CONCRETE FLOOR]

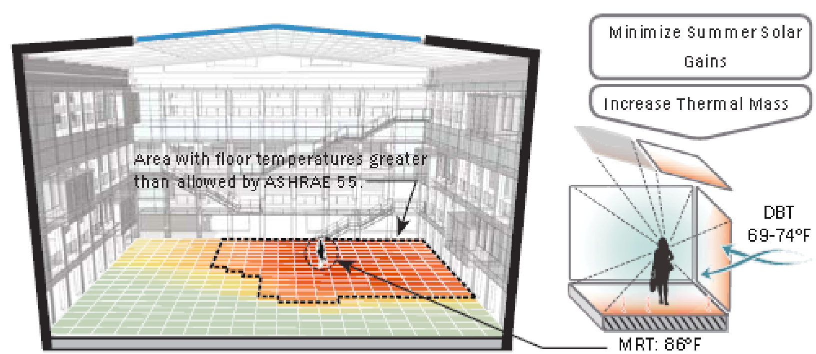


FIGURE 4: OPTION 2 - REDUCED SKYLIGHT SHGC + INCREASED THERMAL MASS [SHGC: 0.25][8" CONCRETE FLOOR]

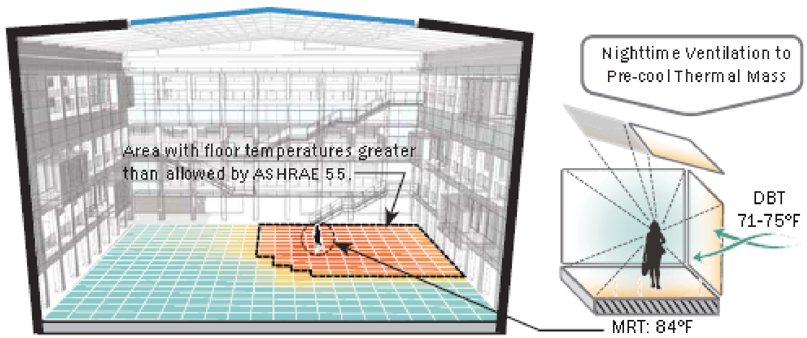


FIGURE 5: OPTION 3 - REDUCED SHGC + THERMAL MASS + NIGHT-FLUSH MECHANICAL VENTILATION [SHGC: 0.25][8" CONCRETE]

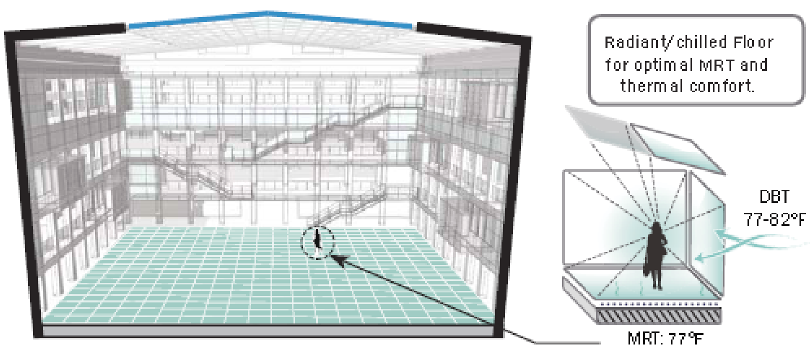


FIGURE 6: OPTION 4 - RADIANT FLOOR COOLING + THERMAL MASS [SHGC: 0.25][8" CONCRETE FLOOR]

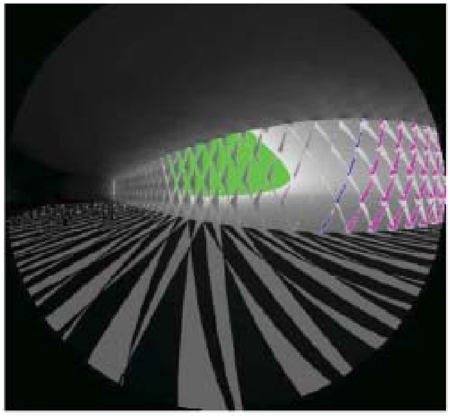
Visual Comfort

- Goal: minimize glare probability

Daylight Glare Probability Criteria

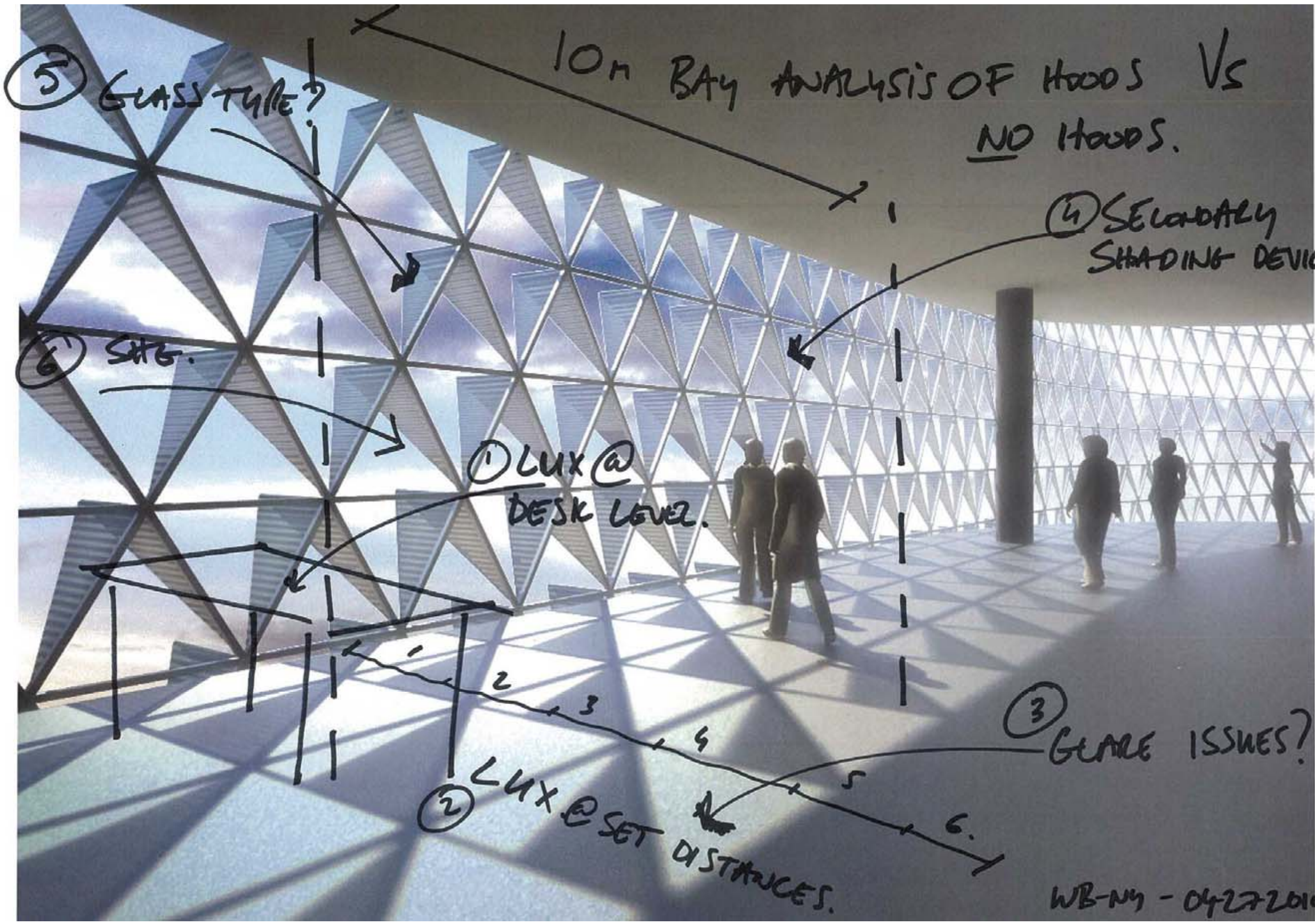
	0.900	Direct Sunlight
High	0.448	Disturbing
Med	0.398	Perceptible
Low	0.352	Imperceptible


Top Hood 700 mm


Side Hood 700 mm

Northeast Top Hood

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8:00 AM	0.403	0.410	0.403	1.000	1.000	1.000	1.000	1.000	0.426	0.431	0.414	0.397
9:00 AM	0.418	0.445	0.478	1.000	1.000	1.000	1.000	0.470	0.486	0.437	0.413	0.405
10:00 AM	0.401	0.420	0.470	0.496	1.000	1.000	1.000	0.497	0.461	0.402	0.391	0.386
11:00 AM	0.376	0.380	0.410	0.447	0.465	0.466	0.472	0.457	0.398	0.362	0.365	0.361
12:00 PM	0.342	0.343	0.355	0.380	0.403	0.415	0.416	0.387	0.344	0.324	0.323	0.329
1:00 PM	0.306	0.303	0.314	0.331	0.343	0.351	0.353	0.336	0.309	0.298	0.300	0.300
2:00 PM	0.288	0.295	0.299	0.292	0.297	0.302	0.304	0.296	0.293	0.289	0.284	0.286
3:00 PM	0.278	0.283	0.280	0.265	0.262	0.265	0.269	0.267	0.276	0.272	0.274	0.277
4:00 PM	0.268	0.265	0.254	0.241	0.232	0.231	0.236	0.243	0.248	0.256	0.263	0.267
5:00 PM	0.251	0.244	0.232	0.218	0.211	0.209	0.213	0.219	0.227	0.234	0.242	0.249


10m BAY ANALYSIS OF HOODS VS NO HOODS.
5 GLASS TYPE?
4 SECONDARY SHADING DEVICES?
6 SHG.
1 LUX @ DESK LEVEL.
1
2
3
4
5
6.
3 GLARE ISSUES?
2 LUX @ SET DISTANCES.
WB-NY - 04272010

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Facade Simulation
Simulating Glass Performance

Two approaches that are most often used by Design Professionals and Energy Analysts.

1. ASHRAE Shading Coefficient Method– U-value /SC method

2. Actual performance – using LBNL WINDOW glazing files

ASHRAE Shading Coefficient Approach

Based on simple definitions for glass U-value and Shading coefficient. Uses a standard 1/8” clear glass pane as a reference point for angular data calculations.

The methodology calculates hourly solar loads using the reference glass and then multiplies by the specified shading coefficient to determine adjusted loads.

Pros:

1. Easy to specify.
2. Does not require use of LBNL Window
3. Does not require knowledge of glazing assembly components.

Cons:

1. Performance based on standard 1/8” glazing
2. As much as 30% error on peak solar loads for multi-pane and coated glazings when angle of incidence is less than 60-degrees
3. Does not account for temperature difference across the window in conduction calcs.
4. Does not account for 2-D conduction edge effects.

Façade Simulation

Glazing: Actual Performance using LBNL WINDOW software

Simulation is based on detailed window model files exported from LBNL WINDOW software. Results are

Pros

1. Correct angular dependence ensures an accurate calculation of solar transmission and absorption.
2. Conductance has the proper dependence on the temperature differentials within the assembly.
3. Allows calculation of 2-D conduction edge effects.

Cons

1. Requires use of additional software.
2. Requires more specific data on glazing assembly: thicknesses, coatings, coating surface and cavity gas.
3. Slower simulation: have to setup model to interpolate angular values hourly to get the best results.

LBNL Window Software

Glazing: Actual Performance data available

Glazing System Library

List
Calc (F9)
New
Copy
Delete
Save
Report

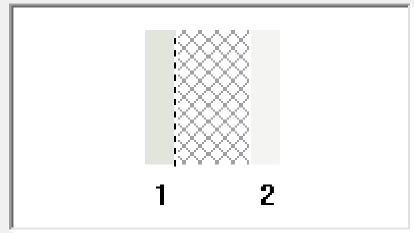
ID #: 15 Name: Solarban 72 with Starphire

Layers: 2 Tilt: 90 ° IG Height: 39.37 inches

Environmental Conditions: New York City Design Conc IG Width: 39.37 inches

Comment:

Overall thickness: 0.946 inches Mode: #



		ID	Name	Mode	Thick	Flip	Tsol	Rsol1	Rsol2	Tvis	Rvis1	Rvis2	Tir	E1	E2	Cond
Glass 1	▸▸	5435	SB72 Starphire_6.PPG	#	0.223	☐	0.307	0.513	0.575	0.775	0.077	0.061	0.000	0.840	0.022	0.578
Gap 1	▸▸	1	Air		0.500	☐										
Glass 2	▸▸	5004	STRPH_6.PPG	#	0.223	☐	0.890	0.078	0.080	0.911	0.082	0.083	0.000	0.840	0.840	0.578

Center of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties

Ufactor	SC	SHGC	Rel. Ht. Gain	Tvis	Keff	Gap 1 Keff
Btu/h-ft2-F			Btu/h-ft2		Btu/h-ft-F	Btu/h-ft-F
0.228	0.360	0.313	75.4	0.710	0.0149	0.0149

Angular Data

Reference 1/8” single pane used by ASHRAE SC method

Glazing System Angular Properties

	0	10	20	30	40	50	60	70	80	90	Hemis
Tsol	0.834	0.833	0.831	0.827	0.818	0.797	0.749	0.637	0.389	0.000	0.753
Abs1	0.091	0.092	0.094	0.096	0.100	0.104	0.108	0.110	0.105	0.000	0.101
Rfsol	0.075	0.075	0.075	0.077	0.082	0.099	0.143	0.253	0.506	1.000	0.136
Rbsol	0.075	0.075	0.075	0.077	0.082	0.099	0.143	0.253	0.506	1.000	0.136
Tvis	0.899	0.899	0.898	0.896	0.889	0.870	0.822	0.705	0.441	0.000	0.822
Rfvis	0.083	0.083	0.083	0.085	0.091	0.109	0.156	0.272	0.536	1.000	0.148
Rbvis	0.083	0.083	0.083	0.085	0.091	0.109	0.156	0.272	0.536	1.000	0.148
SHGC	0.860	0.860	0.859	0.855	0.847	0.827	0.780	0.669	0.420	0.000	0.783

Actual data for a multi-pane high performance glazing assembly.

Glazing System Angular Properties

	0	10	20	30	40	50	60	70	80	90	Hemis
Tsol	0.282	0.283	0.280	0.275	0.268	0.254	0.223	0.164	0.078	0.000	0.236
Abs1	0.185	0.187	0.192	0.195	0.196	0.198	0.206	0.214	0.178	0.000	0.196
Abs2	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.000	0.003
Rfsol	0.530	0.527	0.525	0.527	0.533	0.545	0.567	0.619	0.741	1.000	0.555
Rbsol	0.555	0.550	0.548	0.549	0.553	0.563	0.589	0.651	0.776	1.000	0.578
Tvis	0.710	0.714	0.704	0.692	0.675	0.640	0.560	0.408	0.192	0.000	0.594
Rfvis	0.126	0.119	0.117	0.120	0.132	0.156	0.202	0.306	0.534	0.999	0.184
Rbvis	0.134	0.126	0.125	0.130	0.144	0.175	0.240	0.388	0.661	1.000	0.215
SHGC	0.313	0.315	0.312	0.308	0.301	0.288	0.259	0.200	0.108	0.000	0.270

Why is Angular Data Important

Solar Radiation Angle of Incidence		0	10	20	30	40	50	60	70	80	SC	SHGC	U	RHG
	ASHRAE SC Referenc	0.834	0.833	0.831	0.827	0.818	0.797	0.749	0.637	0.389				
Manufacturer #1 Best glass	Actual Angular	0.282	0.283	0.28	0.275	0.268	0.254	0.223	0.164	0.078	0.344	0.299	0.286	72.1
	ASHRAE SC method	0.287	0.287	0.286	0.284	0.281	0.274	0.258	0.219	0.134				
	% Error	**2%**	**1%**	**2%**	**3%**	**5%**	**8%**	**16%**	**34%**	**72%**				
Manufacturer #3 Best glass	Actual Angular	0.233	0.235	0.231	0.227	0.221	0.209	0.182	0.132	0.061	0.286	0.319	0.277	67.5
	ASHRAE SC method	0.266	0.266	0.265	0.264	0.261	0.254	0.239	0.203	0.124				
	% Error	**14%**	**13%**	**15%**	**16%**	**18%**	**22%**	**31%**	**54%**	**103%**				
Manufacturer #1 Good glass	Actual Angular	0.353	0.355	0.35	0.344	0.335	0.318	0.279	0.205	0.098	0.44	0.386	0.291	92.6
	ASHRAE SC method	0.367	0.367	0.366	0.364	0.360	0.351	0.330	0.280	0.171				
	% Error	**4%**	**3%**	**4%**	**6%**	**7%**	**10%**	**18%**	**37%**	**75%**				
Manufacturer #2 Good glass	Actual Angular	0.325	0.327	0.322	0.316	0.307	0.29	0.253	0.183	0.084	0.436	0.379	0.293	91
	ASHRAE SC method	0.364	0.363	0.362	0.361	0.357	0.347	0.327	0.278	0.170				
	% Error	**12%**	**11%**	**13%**	**14%**	**16%**	**20%**	**29%**	**52%**	**102%**				
Manufacturer #2 Low-U Higher SHGC glass	Actual Angular	0.39	0.393	0.387	0.38	0.371	0.352	0.31	0.227	0.109	0.47	0.409	0.262	97
	ASHRAE SC method	0.39	0.392	0.391	0.389	0.384	0.375	0.352	0.299	0.183				
	% Error	**1%**	**0%**	**1%**	**2%**	**4%**	**6%**	**14%**	**32%**	**68%**				

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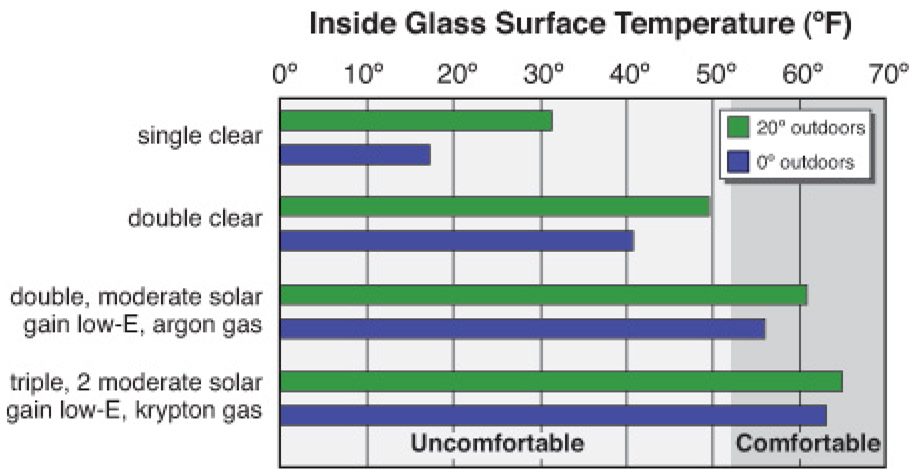
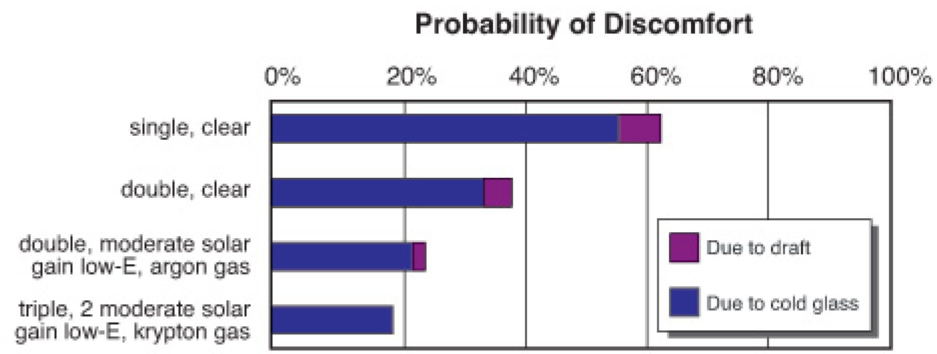
Glass Temperature and Thermal Comfort



Source: Lawrence Berkeley National Laboratory (Lyons and Arasteh).



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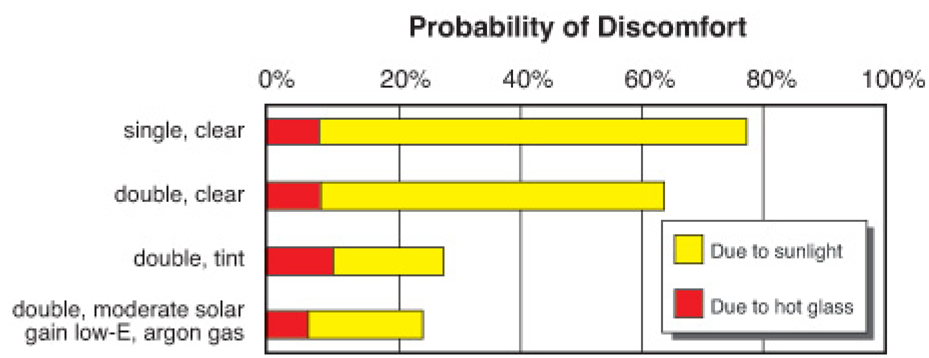

Source: Lawrence Berkeley National Laboratory (Lyons and Arasteh).

The Fanger thermal comfort standard says that the difference in radiant temperature in different directions should be not more than 5C which is about 9F.

If your heating temp is 72F you would target interior glass temp > 63F and if cooling temp is 75F summer glass temp should be <84F.

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Glass Temperature and Thermal Comfort

		ID	Name	Mode	Thick	Flip
Glass 1	▸▸	6046	VE12M.VIR	#	0.223	☐
Gap 1	▸▸	1	Air		0.250	☐
Glass 2	▸▸	103	CLEAR_6.DAT	#	0.225	☐

Center of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties

		Layer 1		Layer 2		
	Outside Air	Outer Surface	Inner Surface	Outer Surface	Inner Surface	Inside Air
Ufactor	-0.4	5.1	6.0	46.8	47.7	69.8
SHGC	89.6	108.5	109.4	91.9	91.3	75.2

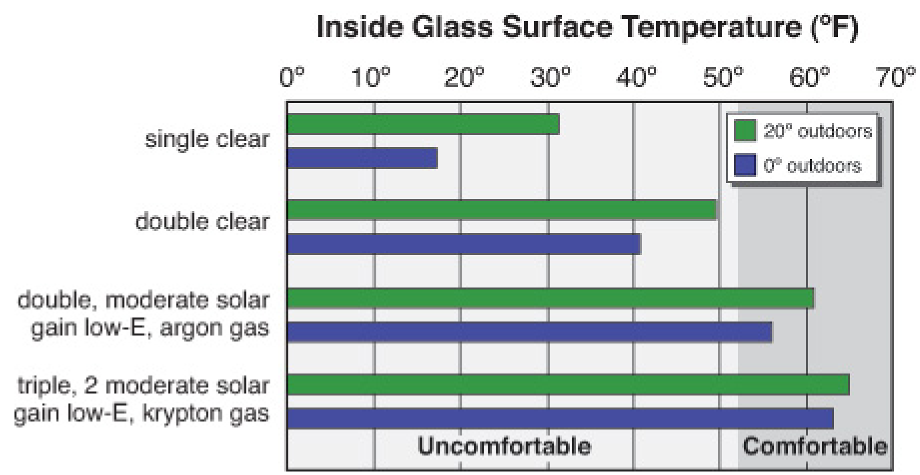
U-Factor = 0.403

		ID	Name	Mode	Thick	Flip
Glass 1	▸▸	6046	VE12M.VIR	#	0.223	☐
Gap 1	▸▸	2	Argon		0.500	☐
Glass 2	▸▸	103	CLEAR_6.DAT	#	0.225	☐

Center of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties

		Layer 1		Layer 2		
	Outside Air	Outer Surface	Inner Surface	Outer Surface	Inner Surface	Inside Air
Ufactor	-0.4	2.9	3.4	55.7	56.2	69.8
SHGC	89.6	110.3	111.4	87.2	86.8	75.2

U-Factor = 0.241



Source: Lawrence Berkeley National Laboratory (Lyons and Arasteh).

Window Frames

Window frames can be explicitly defined in most energy modeling software but rarely are.

1. Most often frame area is assumed to be glass area…it's not and can account for between 5-25% of a windows area.
2. Most software programs require specifying frame thickness, conductance and absorptance of the outside surface.
3. Window frames generally have the following conductance U-values

Vinyl:	0.3 Btu/ft2-F-h
Wood:	0.4 Btu/ft2-F-h
Butt Glazed Curtain wall:	0.7 Btu/ft2-F-h
Thermally broken Aluminum:	1.0 Btu/ft2-F-h
Thermally unbroken aluminum:	1.9 Btu/ft2-F-h

4. Total Frame area can be converted to a uniform frame width using the following equation:

$$(Width_{Win} + Height_{Win})/ 4 * SQRT(0.25*(Width_{Win} - Height_{Win})^2 + Area_{Gl})$$

Win = Window Assembly dimensions and $Area_{Gl}$ = Total Glazed area

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Window Frames

Window Calculation Spreadsheet												
							BASELINE WINDOW ADJUSTMENT FACTOR			Window Consts to		
							% GLASS for Baseline:	40%	Reduce Window sizes in Baseline Model			
							As-Des. % GLASS:	45.60%				
							Multiplier for windows:	0.937				
							Data for eQuest (detailed edit mode)					
	Total Glazed Area (sf)	Fraction Glazed	Frame Area (sf)	Window Width (ft)	Adjusted Height (ft)	Calculated Frame Width (ft)	Calculated Frame Width (in)	Frame Width (ft)	Window Height	Window Width	
North W1	92.62	88%	12.60	15.03	7.00	0.294	3.53	0.294	6.41	14.44	North W1
North W2	117.12	88%	16.52	15.03	8.89	0.356	4.27	0.356	8.18	14.32	North W2
North W3	155.44	90%	17.17	14.88	11.60	0.333	4.00	0.333	10.93	14.21	North W3
North W4	38.50	91%	4.00	5.00	8.50	0.152	1.82	0.152	8.2	4.7	North W4
North W4a	114.14	90%	13.36	15.00	8.50	0.291	3.49	0.291	7.92	14.42	North W4a
West/East (1.4 Seminar)	25.00	85%	4.33	3.67	8.00	0.192	2.30	0.192	7.62	3.28	West/East (1.4 Seminar)
North W5 (café upper)	121.00	100%	0.00	33.00	3.67	0.000	0.00	0.000	3.67	33	North W5 (café upper)
North W5 (café lower)	232.67	100%	0.00	29.08	8.00	0.000	0.00	0.000	8	29.08	North W5 (café lower)
North W5 (café door)	31.33	100%	0.00	3.92	8.00	0.000	0.00	0.000	8	3.92	North W5 (café door)
West/East W4 (staircase)	9.80	74%	3.53	2.00	6.67	0.214	2.57	0.214	6.24	1.57	West/East W4 (staircase)
Raised Roof (W)	132.93	98%	2.22	17.67	7.65	0.044	0.53	0.044	7.56	17.58	Raised Roof (W)
Raised Roof (E)	17.12	93%	1.22	3.75	4.89	0.072	0.86	0.072	4.75	3.61	Raised Roof (E)
Raised Roof (S1)	757.85	98%	13.19	97.60	7.90	0.063	0.76	0.063	7.77	97.47	Raised Roof (S1)
Auditorium East CW	867.48	95%	43.27	36.43	25.00	0.356	4.27	0.356	24.29	35.72	Auditorium East CW
S Parking Vestibule CW/Door (b	127.31	88%	17.19	17.00	8.50	0.346	4.15	0.346	7.81	16.31	S Parking Vestibule CW/Doo
Atrium Floors 3-5 N	156.83	99%	1.93	4.41	36.00	0.024	0.29	0.024	35.95	4.36	Atrium Floors 3-5 N
Atrium Floors 1-2 N	110.77	97%	3.89	4.41	26.00	0.064	0.77	0.064	25.87	4.28	Atrium Floors 1-2 N
Atrium Floors 3-5 NE (below bri	617.00	99%	6.76	27.12	23.00	0.068	0.82	0.068	22.86	26.98	Atrium Floors 3-5 NE (below
Atrium Floors 3-5 NE (R of bridg	69.01	94%	4.44	5.65	13.00	0.121	1.45	0.121	12.76	5.41	Atrium Floors 3-5 NE (R of b
Atrium Floors 3-5 NE (L of bridg	134.77	94%	8.23	11.00	13.00	0.174	2.09	0.174	12.65	10.65	Atrium Floors 3-5 NE (L of b
Atrium Floors 1-2 NE	667.24	95%	37.88	27.12	26.00	0.361	4.33	0.361	25.28	26.4	Atrium Floors 1-2 NE
Atrium Floors 3-5 SE	482.74	97%	14.06	13.80	36.00	0.142	1.70	0.142	35.72	13.52	Atrium Floors 3-5 SE
Atrium Floors 1-2 SE	341.34	95%	17.46	13.80	26.00	0.222	2.66	0.222	25.56	13.36	Atrium Floors 1-2 SE
South CW over Auditorium	551.15	96%	21.92	61.40	9.33	0.156	1.87	0.156	9.02	61.09	South CW over Auditorium
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Code Minimum Window Performance

Code Specified Window Performance

1. Specified as an assembly which includes both glazing and frame areas.
2. No guidance is given about the minimum glass or frame performance as long as the assembly value is met.
3. Area cannot exceed 40% WWR.

How do you model this when proposed fenestration is not specified as an Assembly but rather as separate components?

Code Minimum Window Performance

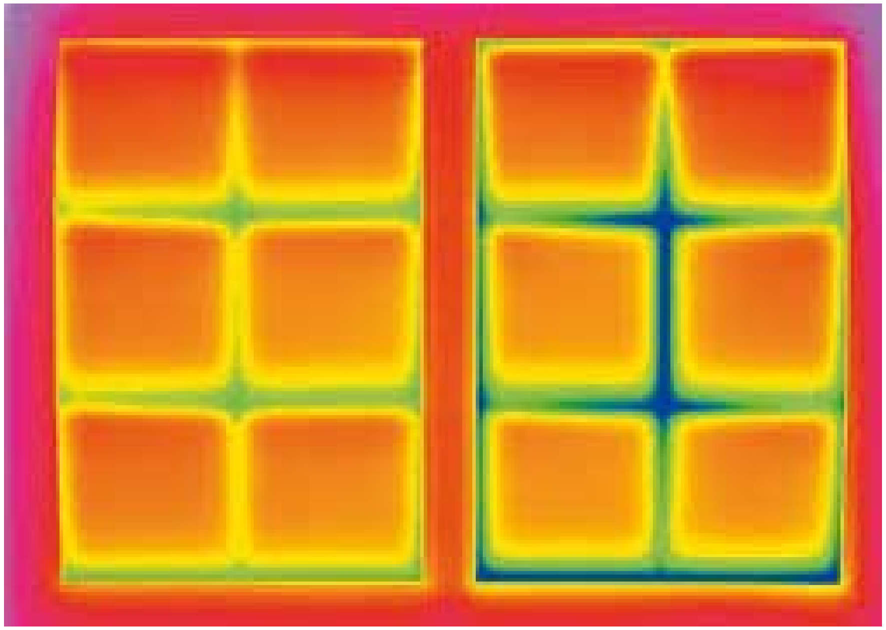
Window Consts to put into eQuest Baseline			Frame	Glass	ASHRAE90.1-2004		Fixed	Operable	North	S, E, W
/indow sizes		U	0.9	0.5540			0.57	0.57		
ine Model		SHGC	0	0.4220					0.4	0.4
							0.570	0.400	0.57	0.40
	Required By ASHRAE90.1-2004 Baseline						Calc. ASHRAE90.1-200		eQuest Baseline	
		Total window	window	combined			Assembly Total		Assembly	
	QTY.	Area (sf)	oper. Area	U value	North	S,E,W	U	SHGC	U-Value	SHGC
North W1	2	210	63.7	0.57	0	2	0.57	0.40	0.60	0.37
North W2	8	1069	254.9	0.57	0	8	0.57	0.40	0.60	0.37
North W3	2	345	0.0	0.57	0	2	0.57	0.40	0.59	0.38
North W4	6	255	0.0	0.57	0	6	0.57	0.40	0.59	0.38
North W4a	1	128	0.0	0.57	0	1	0.57	0.40	0.59	0.38

Answer: Calculate it based on the proposed fenestration design

1. Solve for glass performance assuming frames are thermally unbroken.
2. Calculate glass performance so that the area-weighted window assembly performance meets code
3. Area cannot exceed 40% WWR and must be adjusted for first.
4. With actual glazing performance criteria it is much easier to select an actual glazing assembly to simulate.
5. Iterate with small adjustments to the frame U-factor to fine tune glazing criteria.

Note that the glazing SHGC is higher than the minimum assembly SHGC. This is due to proper accounting of framing which has an SHGC of ~0.

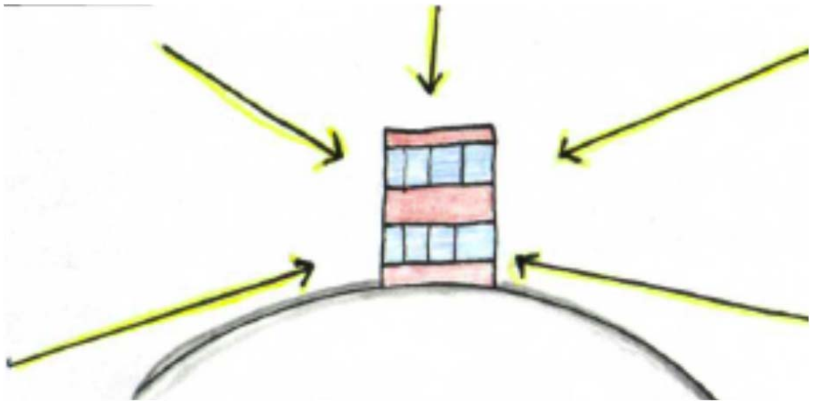
Edge of Glass Effects



Edge-of-Glass Effects
Because of two-dimensional heat conduction effects in multipane windows, the U-value of the edge-of-glass region (a 2.5-in wide border strip at the boundary of the glazing) differs from the U-value in the center-of-the-glass region (the central part of the glazing). The edge-of-glass U-value depends on the center-of- glass U-value and the type of spacer used to separate the panes.

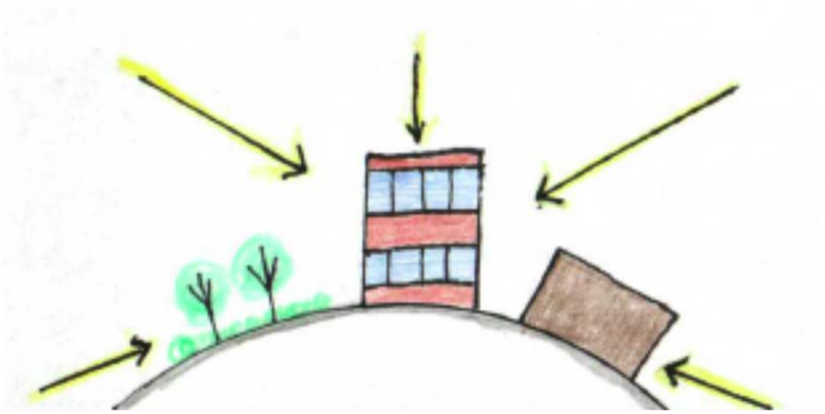
External Shading is Important

…but most often ignored



Theoretical Energy Model Case:

Solar Radiation strikes the façade anytime it is above the horizon without external shading



Reality:

External shading from adjacent structures and fauna significantly reduces the total annual solar radiation striking the building façade.

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Conclusions:

Energy Analysis of Building Facades can be significantly improved by:

1. Use LBNL Window angular performance model data.
2. Account for actual frame areas based on the proposed building design.
3. Use LBNL WINDOW performance criteria in the baseline model by solving for glass performance criteria that maintains minimum fenestration assembly performance.
4. Properly account for external shading