CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

Second Stakeholder Meeting for
Advanced Daylighting Design

March 30th 2017

Mudit Saxena

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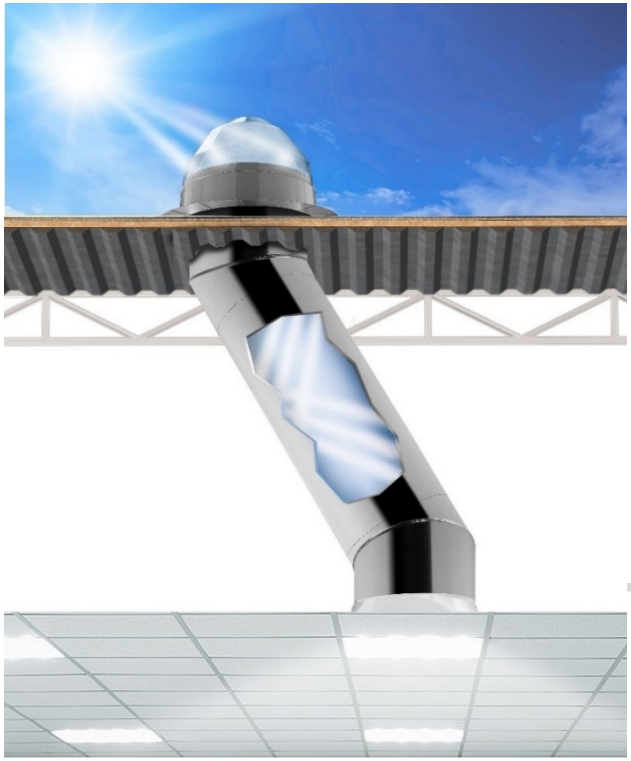
1. Background

Introduction – Proposed Code Changes

1. An interpretation of the Minimum Visible Transmittance (Min VT) requirement for plastic skylights (Table 140.3-C) is proposed for Tubular Daylighting Devices (TDDs)



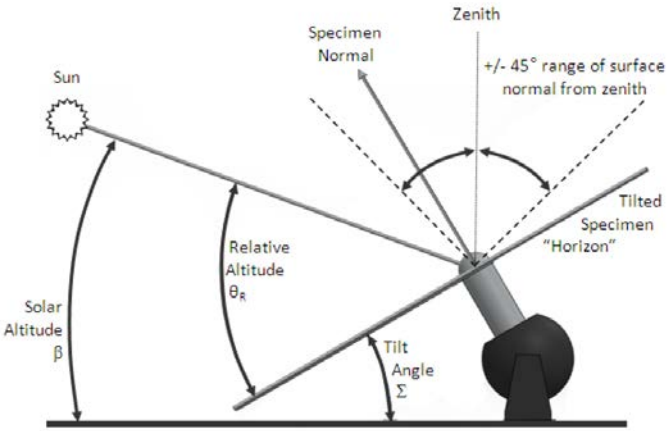
Images credit: Solatube, Sunoptics

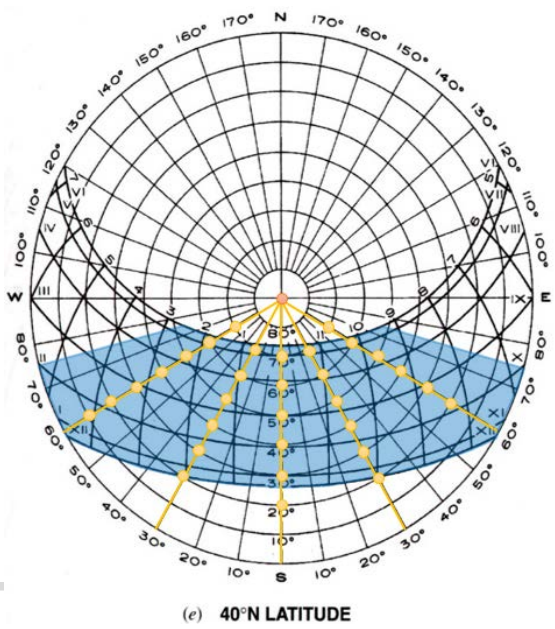
Introduction – Proposed Code Changes

2. An update to:
   i. Skylit Daylit Zone definition to ensure proper interpretation for skylights in atriums
   ii. Sidelit Daylit Zones definition for cases with large exterior overhangs

Proposal 1: Context

- NFRC 203-2014 – A new Test Apparatus and Methodology for Determining the VT_{annual} Product Rating for Optically-Complex TDDs
  - Rates a TDD product under **multiple different angles** of incidence





Images credit: Solatube

Proposal 1: Relevant Code History

- Existing requirements in Title 24, Part 6

  SECTION 110.6 – Mandatory Requirements For Fenestration Products And Exterior Doors

  (a) 4. Visible Transmittance (VT). The fenestration product's VT shall be rated in accordance with NFRC 200 or ASTM E972, for **tubular skylights VT shall be rated using NFRC 203**

Proposal 1: Relevant Code History

Table 140.3-B Prescriptive Envelope Criteria

CONTINUED: TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)

				All Climate Zones			
				Fixed Window	Operable Window	Curtainwall or Storefront	Glazed Doors[2]
Envelope	Fenestration	Vertical	Area-Weighted Performance Rating	Max U-factor	0.36	0.46	0.41	0.45
				Max RSHGC	0.25	0.22	0.26	0.23
			Area-Weighted Performance Rating	Min VT	0.42	0.32	0.46	0.17
			Maximum WWR%	40%			
		Skylights			Glass, Curb Mounted	Glass, Deck Mounted	Plastic, Curb Mounted	
			Area-Weighted Performance Rating	Max U-factor	0.58	0.46	0.88	
				Max SHGC	0.25	0.25	NR	
			Area-Weighted Performance Rating	Min VT	0.49	0.49	0.64	
			Maximum SRR%	5%			

This values does not represent VTannual for TDDs using **NFRC 203**

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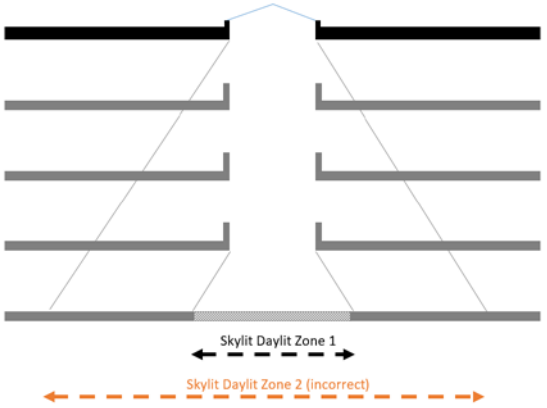
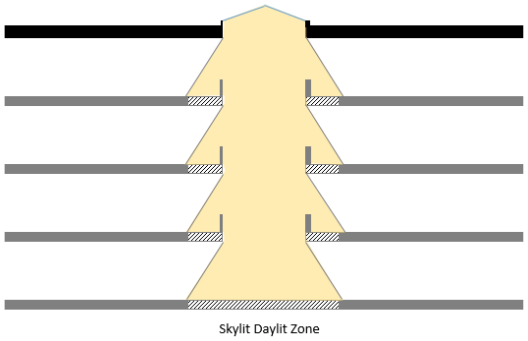
Proposal 2: Context

- Skylit daylit zone definition applied to atrium spaces leaves ambiguity and can be misinterpreted



OR



OR ???

Proposal 2: Context

- Cases with very large opaque overhangs can cause loss in daylighting savings, which current Sidelit Daylit Zone definition does not acknowledge

2. Proposed Code Changes

Proposal 1: Proposed Code Change

- Our analysis points to an equivalent Min VT for TDDs of 0.38
  - This is proposed as a new column within Table 140.3-B

CONTINUED: TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)

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		Skylights			Glass, Curb Mounted	Glass, Deck Mounted	Plastic, Curb Mounted	Tubular Daylighting Devices
			Area-Weighted Performance Rating	Max U-factor	0.58	0.46	0.88	0.88
				Max SHGC	0.25	0.25	NR	NR
			Area-Weighted Performance Rating	Min VT / Min VT_{annual}	0.49	0.49	0.64	0.38
			Maximum SRR%	5%				

Proposal 2: Proposed Code Change

SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

(d) Automatic Daylighting Controls

1. Daylit Zones shall be defined as follows:

Edits to make language cleaner & more direct

A. **SKYLIT DAYLIT ZONE** is the rough area in plan view under each skylight, plus 0.7 times the average ceiling height in each direction from the edge of the rough opening of the skylight, minus any area on a plan beyond a permanent obstruction that is taller than ~~the following: A permanent obstruction that is taller than~~ one-half the distance from the floor to the bottom of the skylight. The bottom of the skylight is measured from the bottom of the skylight well for skylights having wells, or the bottom of the skylight if no skylight well exists.

For the purpose of determining the skylit daylit zone, the geometric shape of the skylit daylit zone shall be identical to the plan view geometric shape of the rough opening of the skylight; for example, for a rectangular skylight the skylit daylit zone plan area shall be rectangular, and for a circular skylight the skylit daylit zone plan area shall be circular.

New addition

For skylight(s) located in an atrium, the skylit daylit zone shall include the floor area directly under the atrium, and the top floor that is directly under the skylight, plus 0.7 times the average ceiling height for that floor, in each direction from the edge of the rough opening of the skylight, minus any area on a plan beyond a permanent obstruction that is taller than one-half the distance from the top floor to the bottom of the skylight.

Proposal 2: Proposed Code Change

Consistent with exception in ASHRAE 90.1

EXCEPTION 1 to 130.1(d)1A: Areas under skylights where it is documented that existing adjacent structures or natural objects block direct sunlight for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.

Edits to make language cleaner & more direct

B. **PRIMARY SIDELIT DAYLIT ZONE** is the area in plan view ~~and is~~ directly adjacent to each vertical glazing in an exterior wall, one window head height deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window, minus any area on a plan beyond a permanent vertical obstruction that is 6 feet or taller as measured from the floor.

C. **SECONDARY SIDELIT DAYLIT ZONE** is the area in plan view ~~and is~~ directly adjacent to the each vertical glazing, two window head heights deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window, minus any area on a plan beyond a permanent vertical obstruction that is 6 feet or taller as measured from the floor.

Note: Modular furniture walls shall not be considered a permanent obstruction.

New addition

EXCEPTION to 130.1(d)1B&C: Areas adjacent to windows with overhangs and no clerestory above the overhang, where the ratio of the Overhang Projection to the Window Head Height is greater than 1.0.

Feedback

Let's move on to…

Analysis

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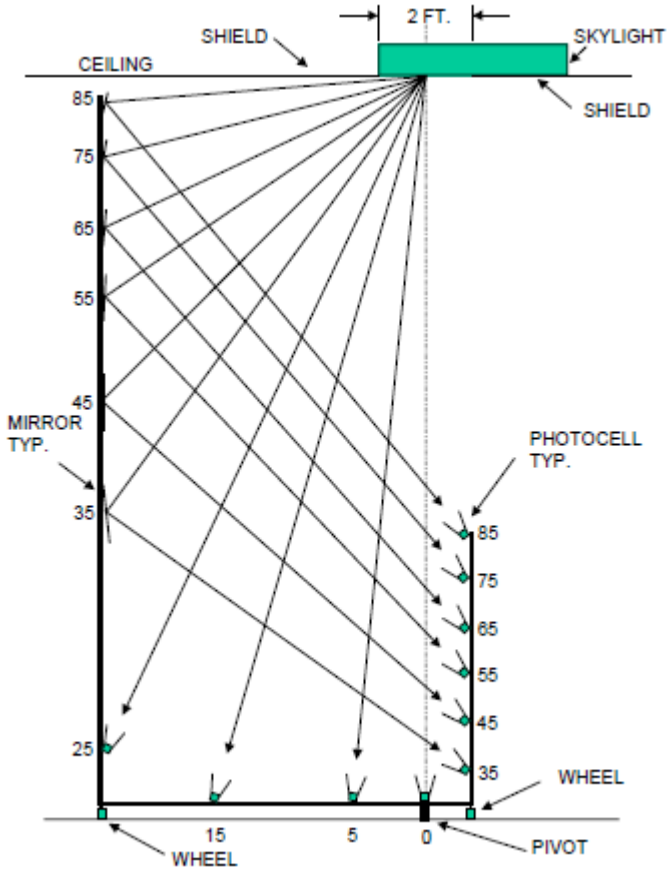
3. Analysis

Proposal 1: Analysis



PIER Skylight Photometric Testing Data (HMG 2003)

- 8 skylights (22 skylight/light well combinations) tested using a Skylight Goniophotometer
  - A goniophotometer measures luminous flux at various angles from the luminous source.
  - Skylights were tested at 10o increments of solar altitude angles (location Scottsdale, AZ 33^{o} N lat)
  - Results combined mathematically to create a photometric file (.ies)

Proposal 1: Analysis

- PIER study tested traditional skylights typically used for commercial building applications

Figure 15. Double-glazed Low-E Flat Skylight – Type A

Figure 16. Single-glazed White Acrylic Dome Skylight – Type C.

Figure 17. Double-glazed White Acrylic Dome Skylight – Type D.

Figure 18. Double-glazed Prismatic Acrylic Arch Skylight – Type E.

Figure 19. Fiberglass Pyramidal Skylight – Type F.

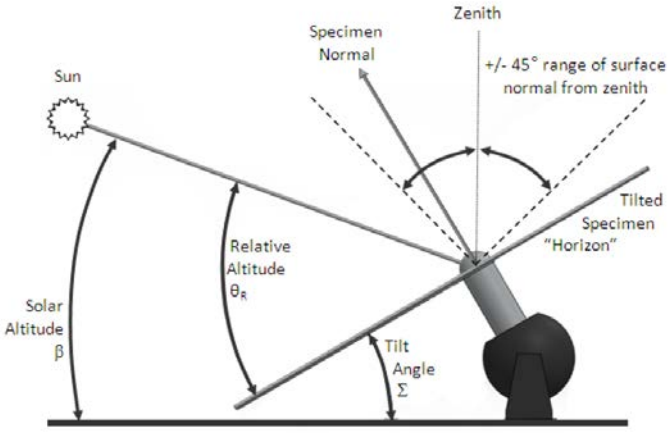
Figure 20. Twinwall Polycarbonate Pyramidal Skylight – Type G.

Figure 21. Bronze Acrylic Pyramidal Skylight – Type H.

Proposal 1: Analysis

NFRC 203 Testing Methodology

- This methodology for traditional skylights, while not identical, is similar to, the one used in NFRC 203 for VTannual for TDDs
  - Where a TDD is mounted on an integrating sphere
  - Transmittance readings are taken at various altitude and azimuth angles relative to the sun.



Proposal 1: Analysis

- Photometric Testing vs. NFRC 203 methodology

	NFRC 203	PIER Photometric Testing
Solar Altitude	10º inc. from 20º to 70º solar alt	10º inc. from 10º to 60º solar alt
Solar Azimuth	3 bins of 0º, 30º and 60º azimuths	various azimuth angles based on the sun's movement (for 30º Lat. location)
Light Well	3ft light well	1ft light well
Testing Procedure	Integrating sphere on a rotating track	Static setup, mirrors used to "fold" the path of light

Proposal 1: Analysis Methodology

- Data from PIER Photometric testing of skylights for different solar altitude angles (10º to 60º) was processed to develop a VTannual rating for each skylight.

$$VT_{annual} = (VT_{20,0}*ZT_{20,0}) + (VT_{30,0}*ZT_{30,0}) + (VT_{40,0}*ZT_{40,0}) + (VT_{50,0}*ZT_{50,0}) + (VT_{60,0}*ZT_{60,0}) + VT_{70,0}*ZT_{70,0}) + (VT_{20,30}*ZT_{20,30}) + (VT_{30,30}*ZT_{30,30}) + (VT_{40,30}*ZT_{40,30}) + (VT_{50,30}*ZT_{50,30}) + (VT_{60,30}*ZT_{60,30}) + (VT_{70,30}*ZT_{70,30}) + (VT_{20,60}*ZT_{20,60}) + (VT_{30,60}*ZT_{30,60}) + (VT_{40,60}*ZT_{40,60}) + (VT_{50,60}*ZT_{50,60}) + (VT_{60,60}*ZT_{60,60}) + (VT_{70,60}*ZT_{70,60});$$

Where:

VT_{annual} = Total Annual Visible Transmittance of TDD

$VT(\theta_R, \gamma)$ = Visible transmittance at one RSALT angle and one surface-solar azimuth angle

ZT = Zonal Time Factor

Table 8-1 Zonal Time (ZT) Factors

Relative Solar Altitude Angle (RSALT), θ_R	Surface-Solar Azimuth Angle, γ 0°	30°	60°
20°	0	0.106	0.084
30°	0.074	0.097	0.072
40°	0.034	0.064	0.068
50°	0.026	0.053	0.078
60°	0.023	0.051	0.074
70°	0.029	0.055	0.012

Proposal 1: Analysis Methodology

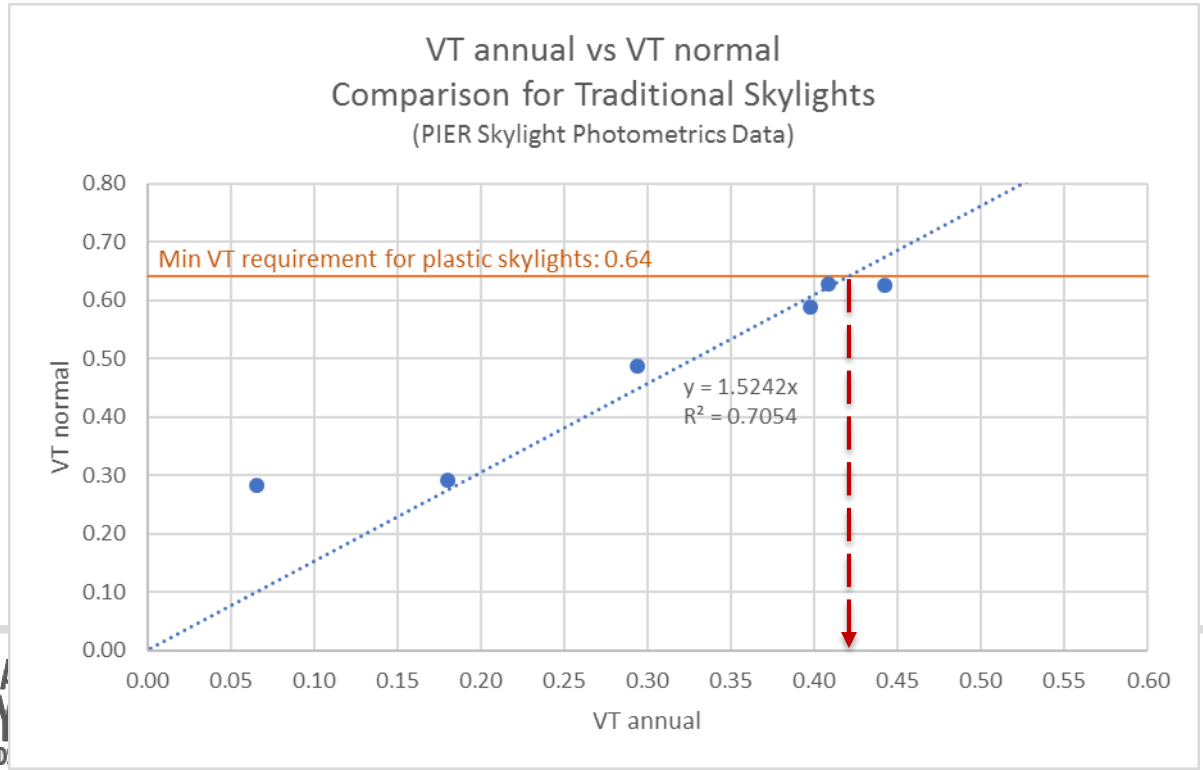
- This rating was compared to the skylight's glazing material Visible Transmittance (VTnormal) for each skylight, obtained using ASTM E972 method.
  - This method rates the visible transmittance of a sample of the glazing material and is currently the only accepted method for rating visible transmittance of projecting skylights.

Solar Altitude Angles >>	10	20	30	40	50	60	70*	VT annual	VT normal
Crystal over crystal Fiberglass ins panel pyramid	0.129	0.162	0.178	0.209	0.222	0.244	0.244	0.203	0.292
Double glazed clear prismatic acrylic compound arch (90deg turned)	0.378	0.393	0.437	0.448	0.501	0.54	0.54	0.466	0.6275
Double glazed clear prismatic acrylic compound arch	0.453	0.507	0.379	0.362	0.354	0.348	0.348	0.389	0.6275
Double glazed white acrylic dome	0.207	0.392	0.396	0.408	0.418	0.431	0.431	0.409	0.587
Single glazed bronze acrylic pyramid (3ft well)	0.047	0.054	0.069	0.076	0.065	0.063	0.063	0.065	0.282
Single glazed white acrylic dome	0.446	0.445	0.464	0.375	0.464	0.446	0.446	0.441	0.626
Single glazed white PET compound arch (90 deg turned)	0.316	0.39	0.37	0.361	0.376	0.377	0.377	0.375	0.488
Single glazed white PET compound arch	0.254	0.213	0.202	0.206	0.21	0.229	0.229	0.213	0.488

* 70deg Solar alltitude angle was estimated as being equal to 60deg

Proposal 1: Analysis Results

- Our analysis shows a linear relationship between VTannual and VTnormal with a slope of 1.5242
- Using this we calculate the equivalent of the Min VT requirement in Title 24 2016 for plastic skylights of 0.64 = 0.42



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Proposal 1: Analysis Results

- The resulting equivalent Min VTannual value is then adjusted to account for the presence of a 3ft light well in the NFRC 203 test procedure for TDDs.
  - A specular, highly-reflective light well has a well efficiency of 0.9 – 0.7
  - Which means light passing through the tube of a TDD reduces by about 10% - 30%
  - The Min VTannual criteria is hence adjusted downward (conservatively) by 10%: 0.42 * 0.9 = **0.38**

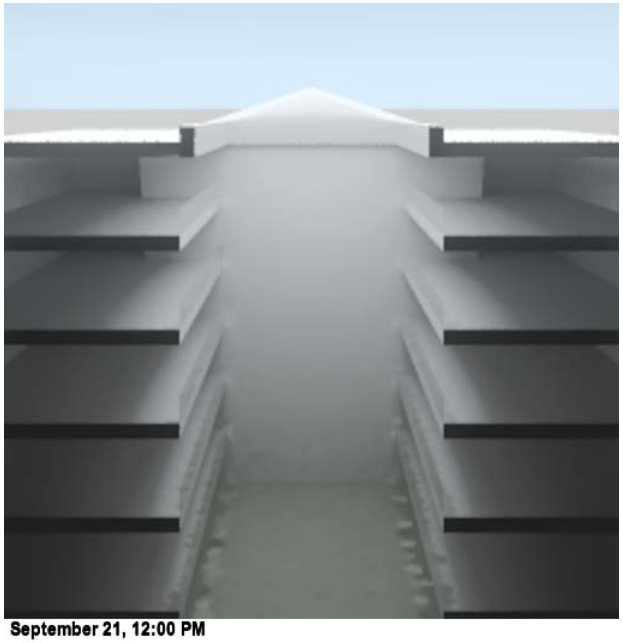
Proposal 1: Qualifying TDD Products

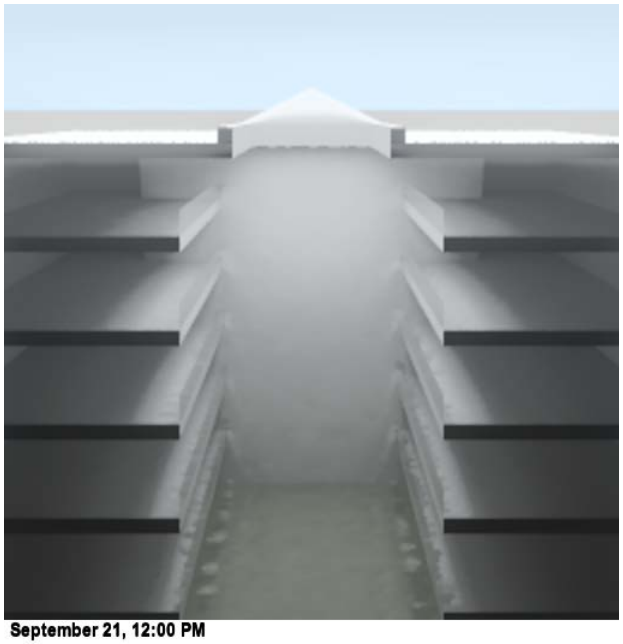
- NFRC's Certified Products Directory (CPD) lists:
  - Number of TDD products: **44**
  - From number of manufacturers: **5**

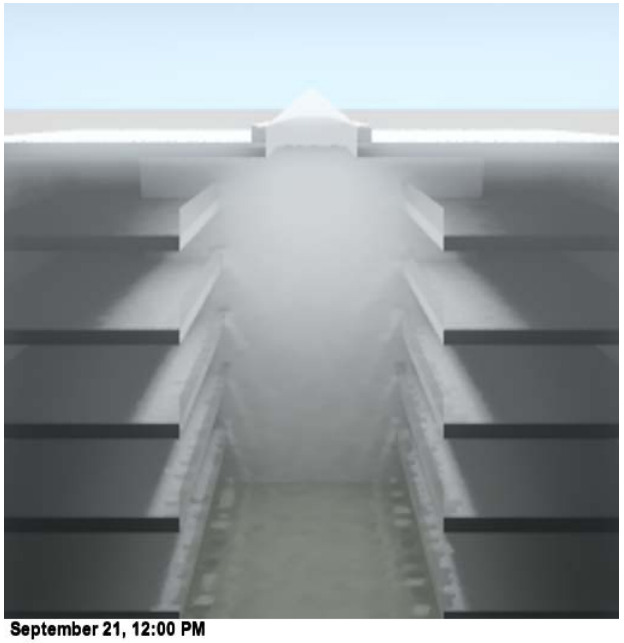
- With a Min VTannual of 0.38:
  - Number of qualifying TDD products: **20**
    (45% of the products in the CPD)
  - From number of manufacturers: **3**

Proposal 2: Analysis

- Radiance simulations show daylight distribution in all floors of a building with atrium
  - 3 Skylight sizes

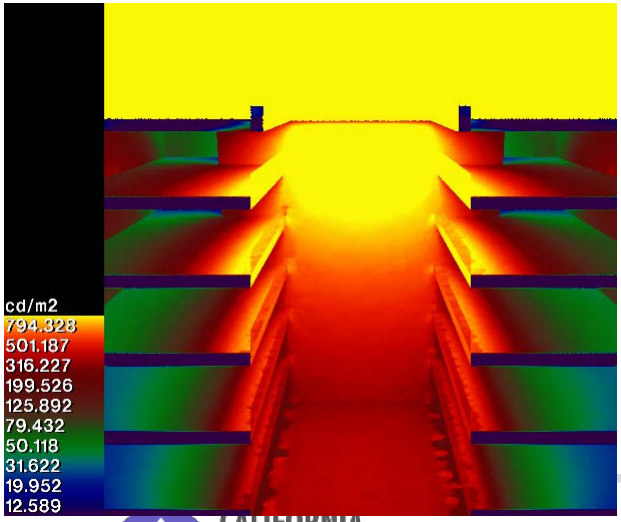


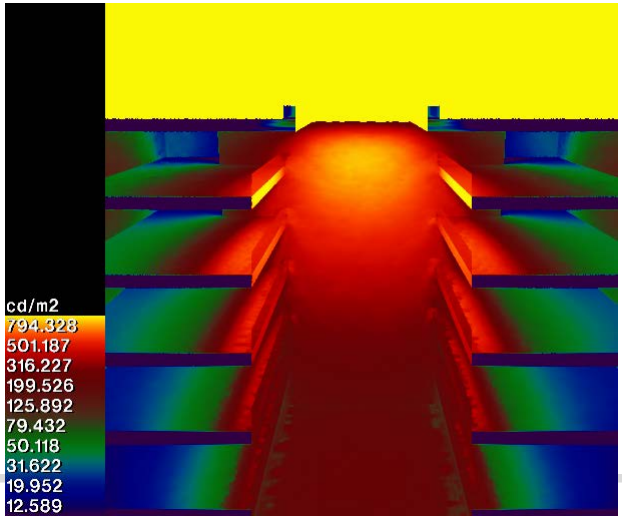


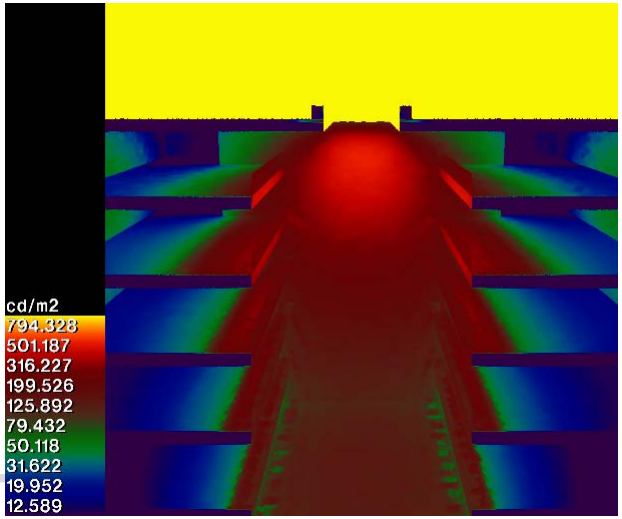


Proposal 2: Analysis

- Radiance false color rendering shows
  - Top floor in 2 cases receives most daylight
  - In the case with smallest skylight, one floor below top has slightly more daylight
  - Variations in atrium geometry, skylight VT, interior reflectance etc. can change results significantly

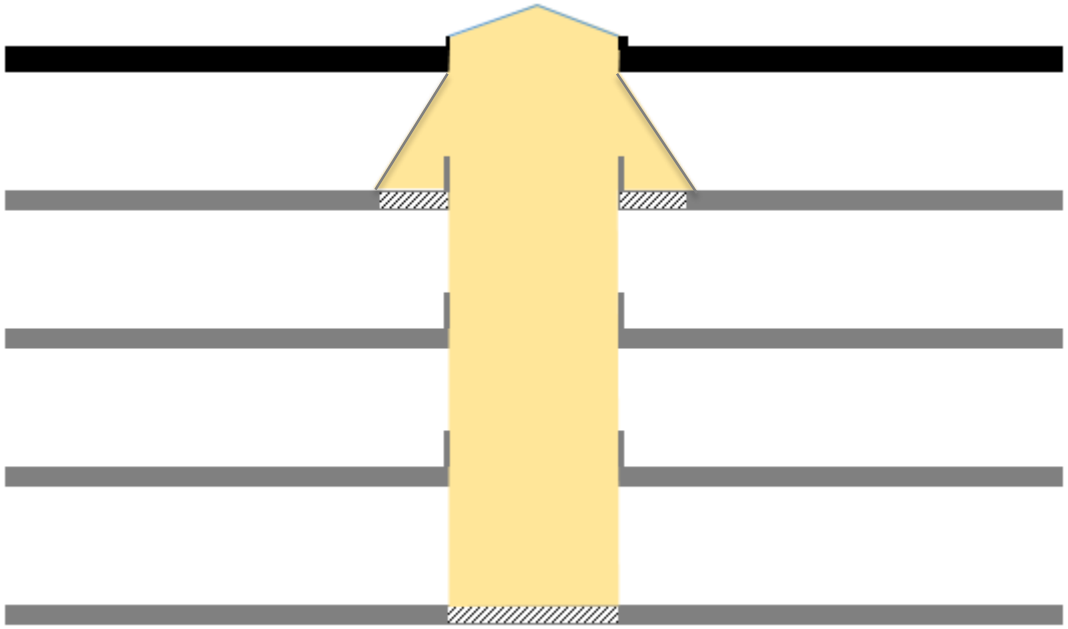






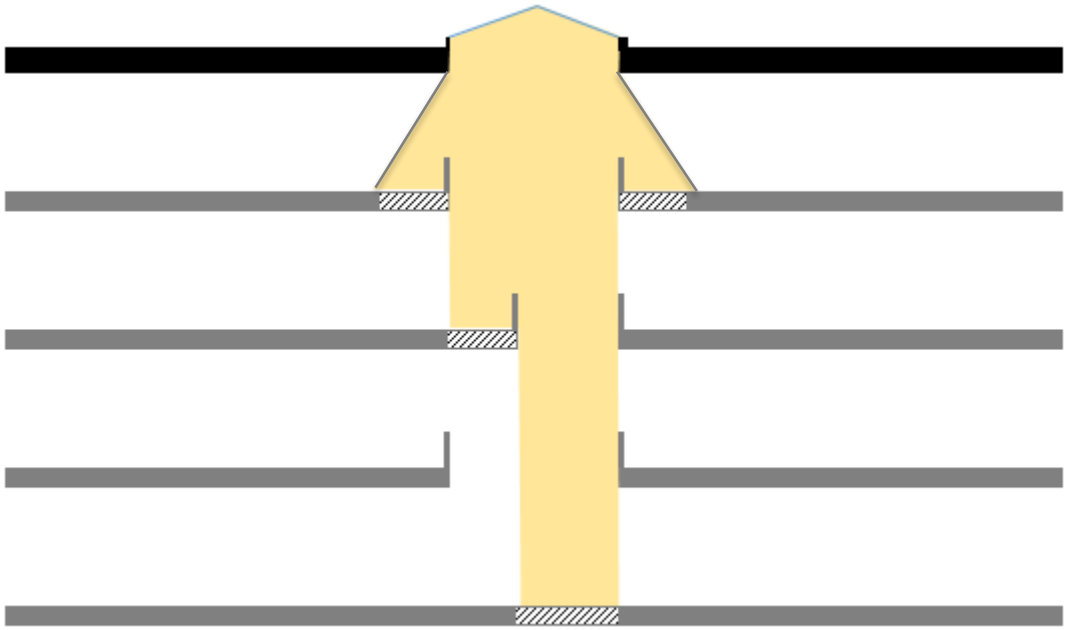
Proposal 2: Analysis

- Resulting skylit daylit zones based on proposed code language
  - Case 1



Proposal 2: Analysis

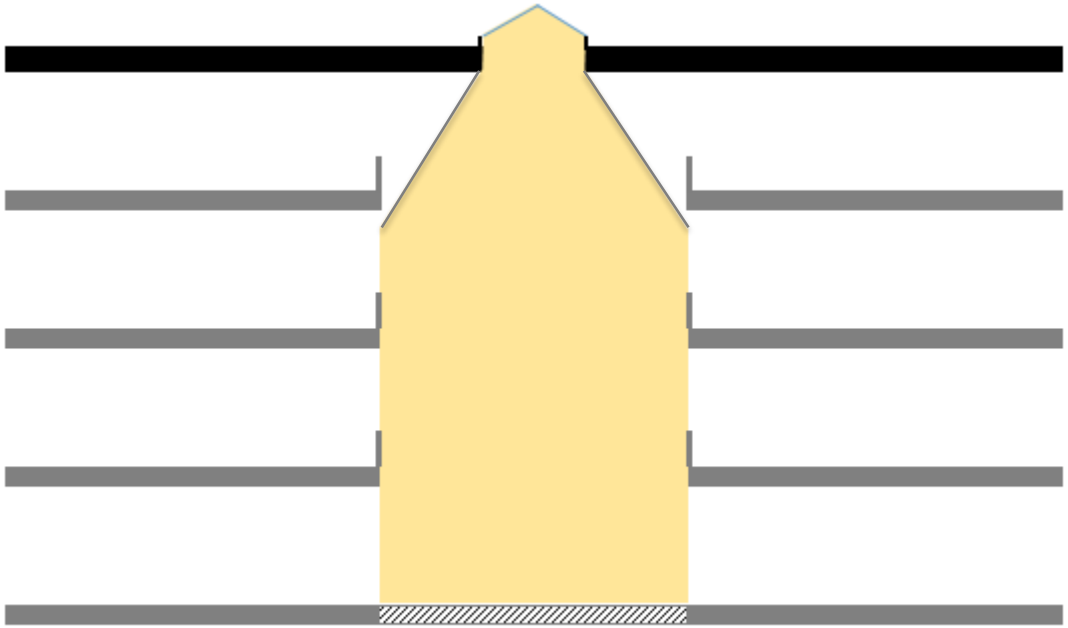
- Resulting skylit daylit zones based on proposed code language
  - Case 2



Skylit Daylit Zone

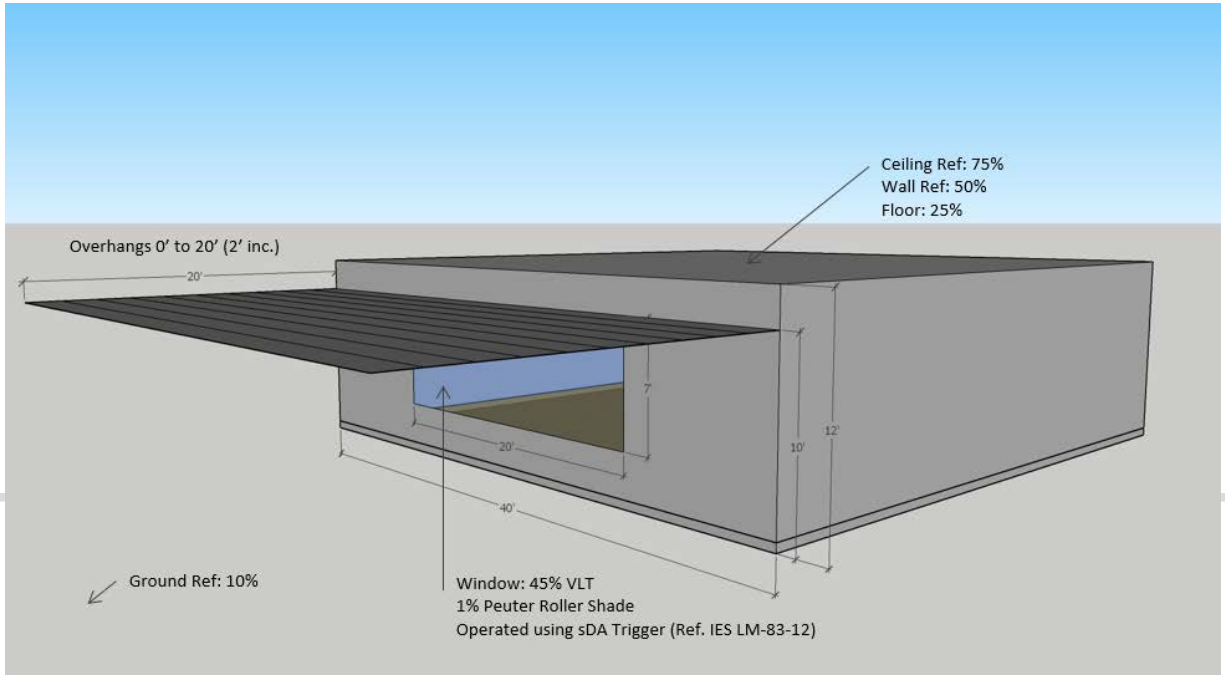
Proposal 2: Analysis

- Resulting skylit daylit zones based on proposed code language
  - Case 3

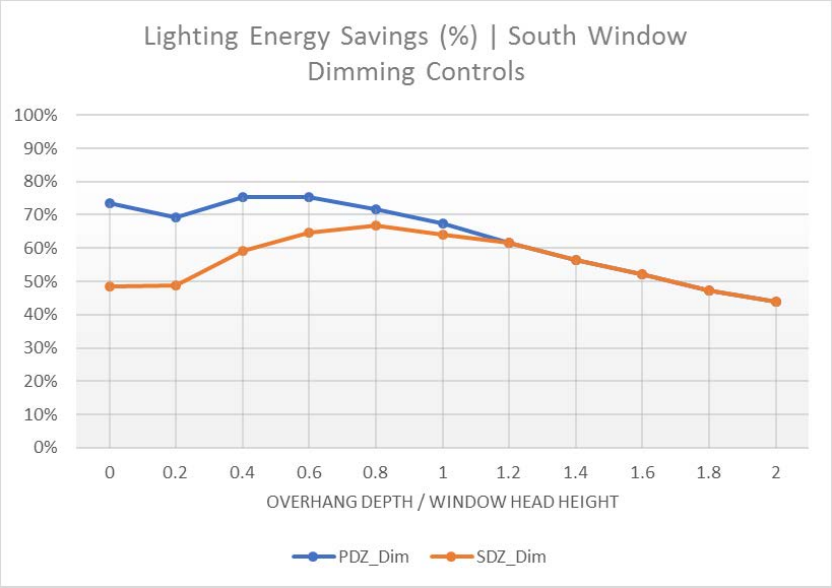


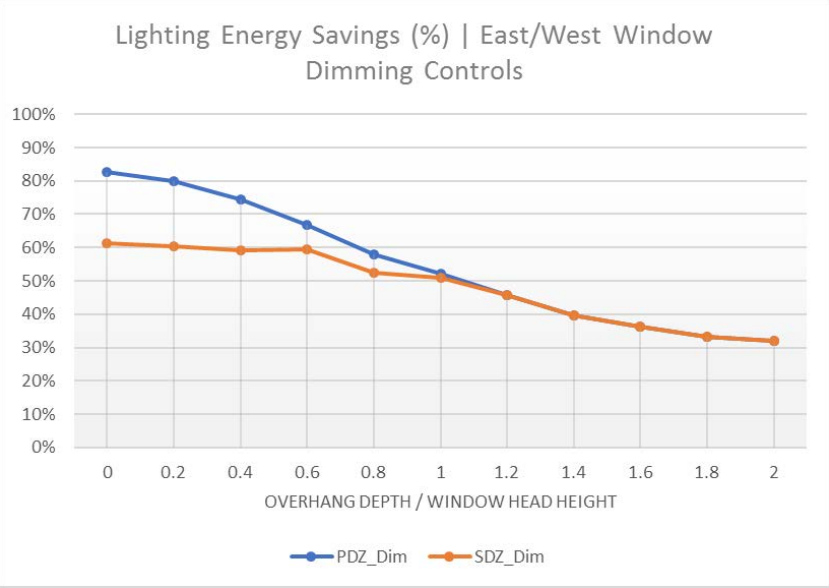
Proposal 2: Analysis

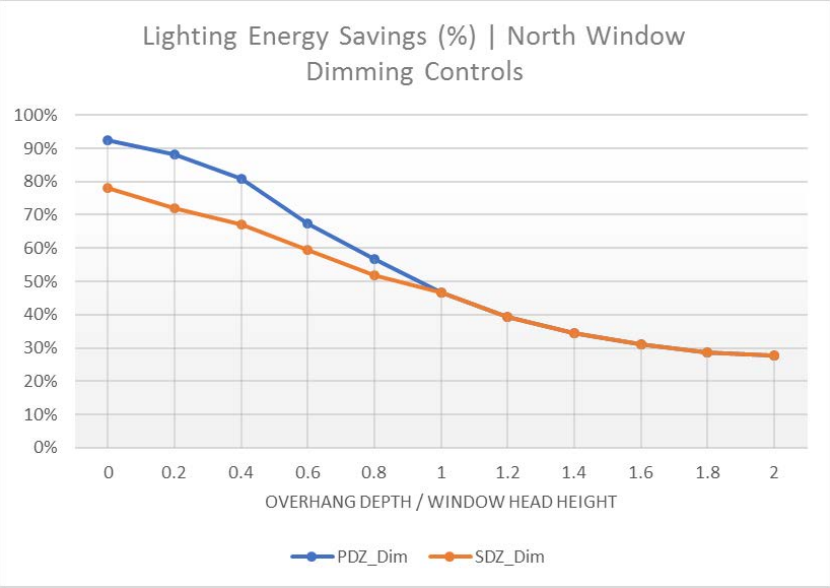
- Radiance simulations show daylight levels for primary and secondary daylit zones for a room with window and overhang
  - Overhang depth parametrically increased from 0ft to 20ft
  - Blinds operated based on direct sun penetration trigger (per IES LM-83-12)



Proposal 2: Analysis Results







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Proposal 2: Analysis Results

- At overhang projection / window head height ratio of 1 – savings in Primary daylit zone reduced by about 50% in N, E, W orientations
- In S orientation, decrease in daylight level is much lower with deeper overhangs.

	% Savings - **DIMMING** Controls					
	SOUTH		EAST/WEST		NORTH	
OH/HH	PDZ	SDZ	PDZ	SDZ	PDZ	SDZ
0	73%	48%	**83%**	**61%**	**92%**	**78%**
0.2	69%	49%	80%	60%	88%	72%
0.4	**75%**	59%	74%	59%	81%	67%
0.6	75%	65%	67%	59%	67%	59%
0.8	72%	**67%**	58%	52%	57%	52%
1	67%	64%	52%	51%	47%	47%
1.2	61%	61%	46%	46%	39%	39%
1.4	56%	56%	39%	39%	34%	34%
1.6	52%	52%	36%	36%	31%	31%
1.8	47%	47%	33%	33%	29%	29%
2	44%	44%	32%	32%	28%	28%

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Bold Max Savings
25% savings loss*
50% savings loss*
75% savings loss*
* compared to savings at OH/HH = 0

Feedback

Let's move on to…

Next Steps

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Next Steps

Next Steps

- Please send any additional feedback within 2 weeks to:
  - CASE Author (see contact info at end of this presentation)
  - Info@title24stakeholders.com

- Keep an eye on Title24Stakeholders.com for:
  - Presentations from today's meeting
  - Draft Code Change Language
  - Notes from today's meeting
  - Draft CASE Report (will be posted in April)

Thank you.

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Appendix

References

- Title24Stakeholders.com
- EnergyCodeAce.com
  - See Reference Ace for 2016 Standards, Appendices, and Compliance Manuals
- California Energy Commission 2019 Standards Webpage
- List references that will be available on Adobe Connect during meeting