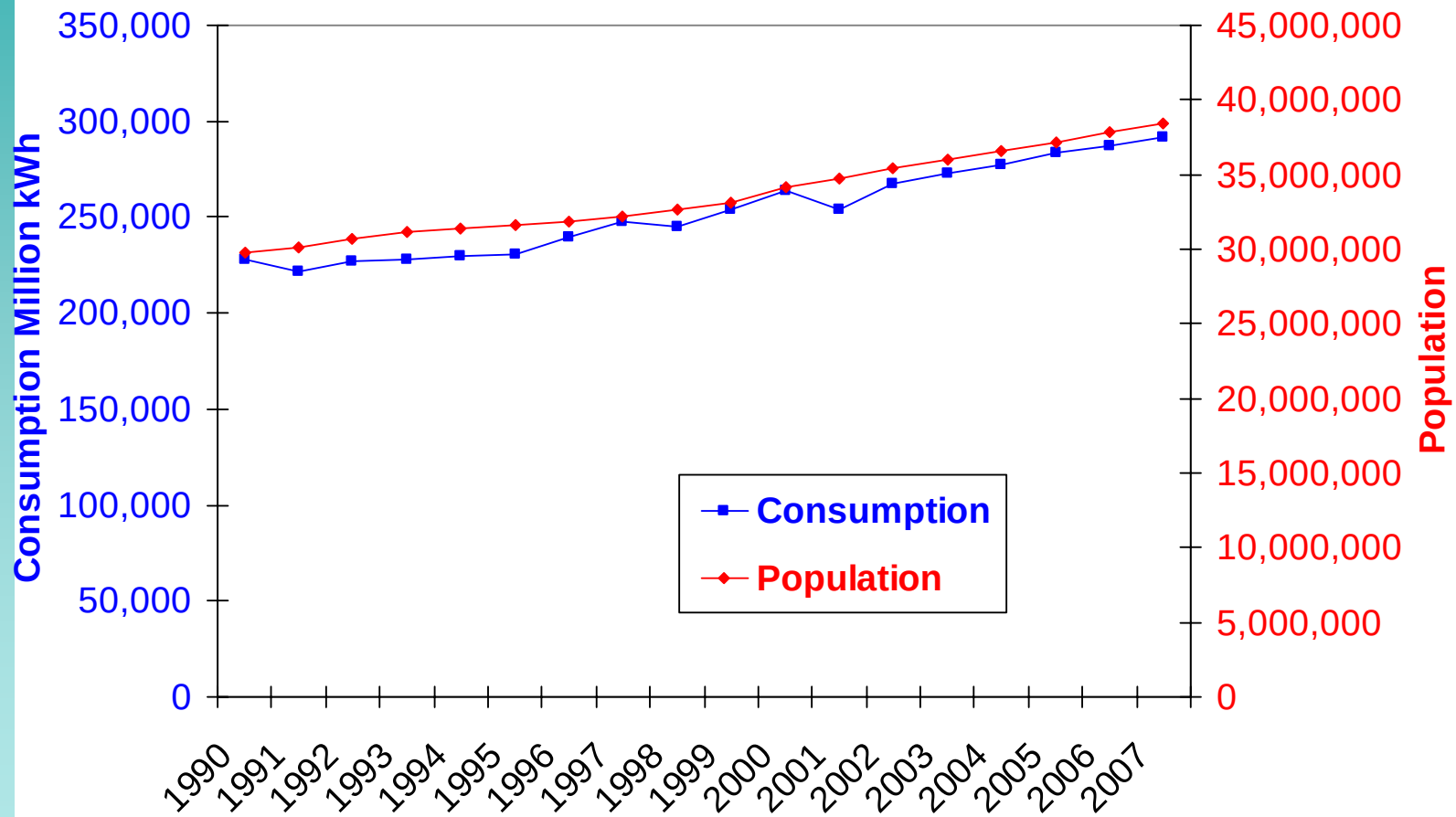
2008 Title 24 Nonresidential CASE Proposals

Presented by

PG&E Codes & Standards Program
July 13, 2006

California Growth



More Background

- Serious constraints on adding generation and transmission capacity
- Energy efficiency less expensive than adding capacity
- State policy: improve and maintain efficiency before adding more electrical capacity

CPUC Efficiency Goals 2006-2008

- Energy efficiency now treated as a generation resource
- Energy Goals:

2005	2006	2007	2008	
459	829	944	1,053	GWh

- IOUs get credit for codes work

PG&E 2008 T-24 CASE Reports

- Codes And Standards Enhancements
- Technical and feasibility information on energy savings proposals to support an informed CEC decision on 2008 Title 24
  - ***Technical information*** - how does it work, how much cost, how much energy and cost savings
  - ***Feasibility*** – market share, can market respond, interaction w/ codes & practices

PG&E Non-Res CASE Studies

- Sign Lighting
- Toplighting
- Sidelighting
- Demand response
  - Sign lighting
  - Indoor Lighting
  - Wiring
- Envelope trade-offs
- HVAC Controls
- Hardwired Standby Loads
- Pool pumping
- Ref warehouses
- Envelope insulation
- Lighting Controls
- Outdoor Lighting
- Indoor Lighting

Indoor and Outdoor Lighting CASE reports also sponsored by SCG and SDG&E

2008 Title 24 Nonresidential CASE Skylighting and Sidelighting Proposal

Jon McHugh, Heschong Mahone Group

In support of

PG&E Codes & Standards Program

Daylighting, Skylighting & Sidelighting

- Daylighting – lighting of building interiors with light from the sun or sky…

… and turning off electric lighting in response

30% of commercial electricity for lighting

- Sidelighting – daylighting though windows
  - and clerestories
- Skylighting - daylighting through skylights
  - and other roof apertures

Current requirements in 2005 standards

- Daylit area defined for skylights and windows
- Separate circuiting and switch (controls) when daylit area > 250 sf
- If daylit area under skylights > 2,500 sf, automatic multi-level daylighting controls required
  - No similar requirement for sidelit spaces
- Lighting control credits (PAF) for photocontrols
  - Based on LPD and EA of skylights
  - Based on VLT and WWR of windows

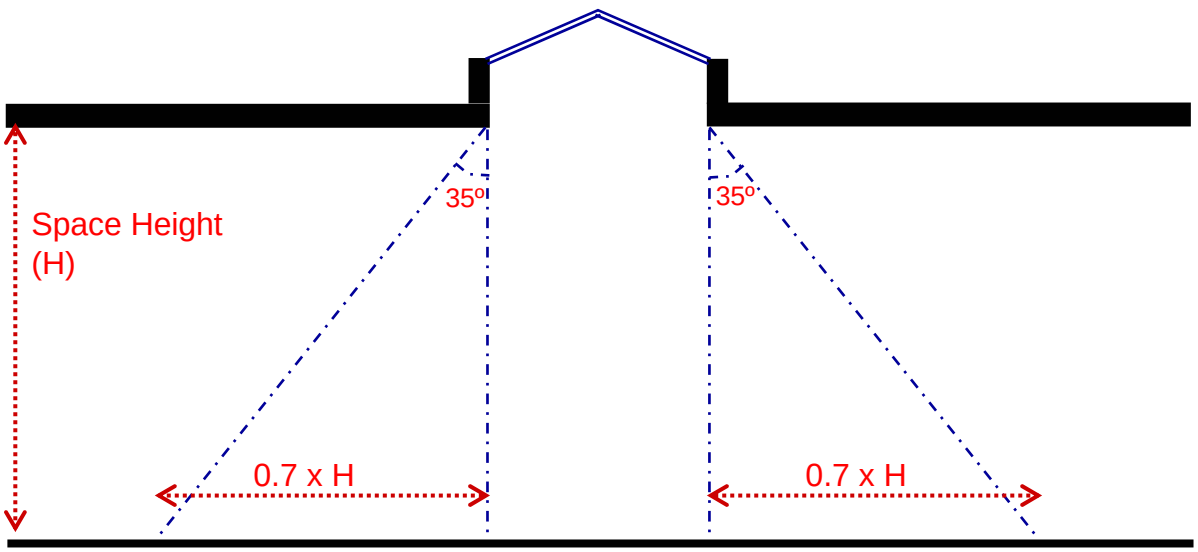
2005 Title 24 Requirement for Minimum Skylight Area §143(c)

- In large low-rise enclosed spaces
  - directly under a roof
  - > 25,000 sf
  - > 15 foot ceiling
  - > 0.5 W/sf general lighting
- Skylights required
  - at least half of floor area in daylit zone
  - skylights with haze (diffusion) greater than 90%
  - minimum skylight area requirements
    - 3% to 3.6% of daylit area depending on LPD

Proposed changes

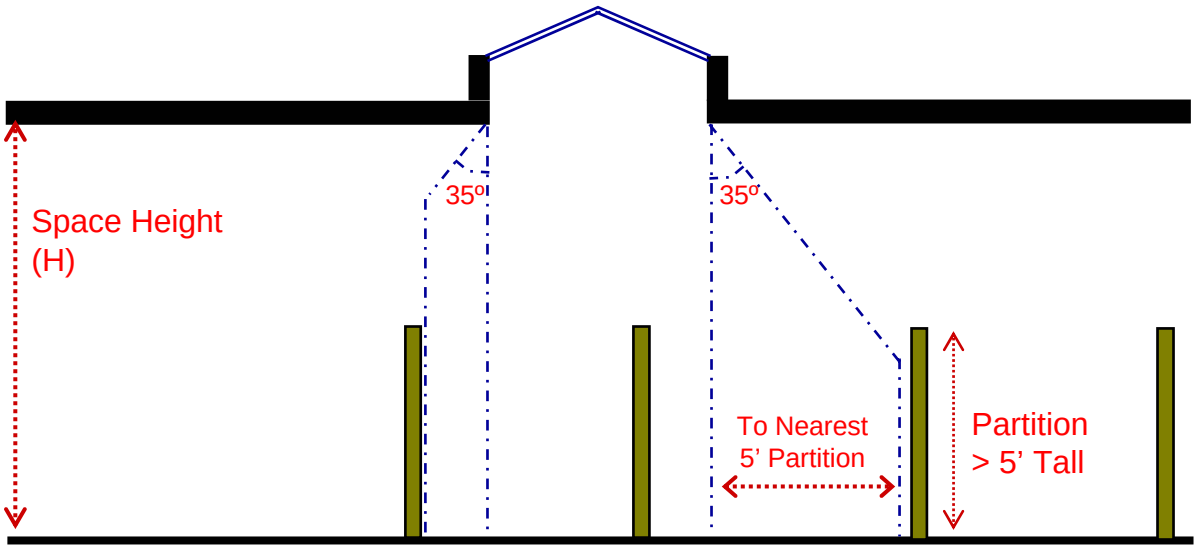
- Slight modification to skylit area under skylights
- Geometry based definition for sidelit area
- Primary vs secondary sidelit area
- Skylighting requirements in spaces > 8,000 sf
- Require multi-level photocontrols when skylight area or primary sidelit area > 2,500 sf
  - Exemptions for low LPDs
- New basis for photocontrol PAFs
- Photocontrol features for all spaces

Skylit area under skylights



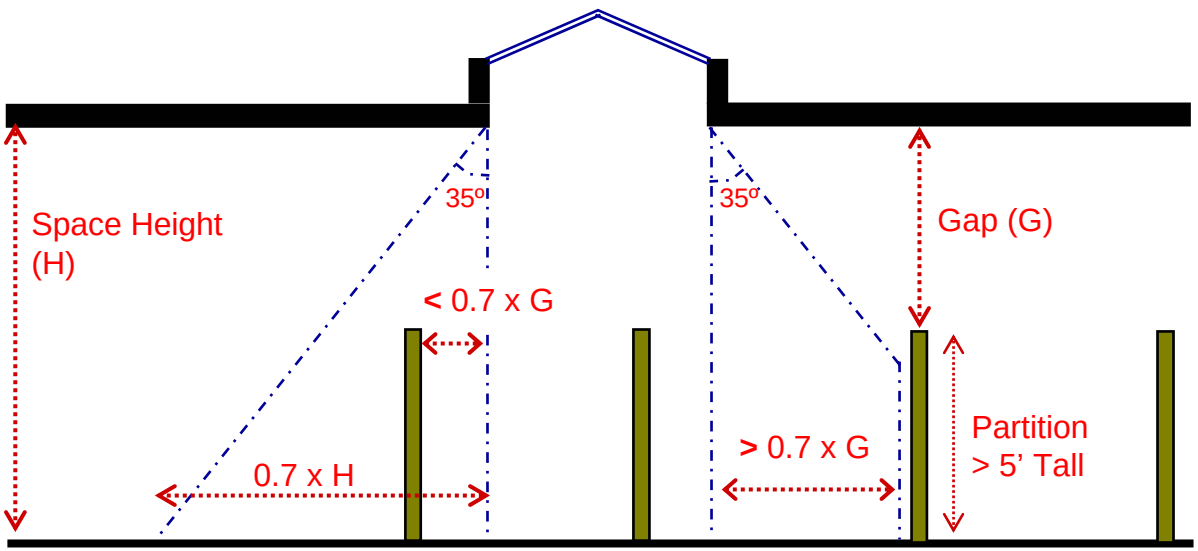
2005 Title 24 Definition of 'Daylit Area'
Without Partitions

Skylit area under skylights



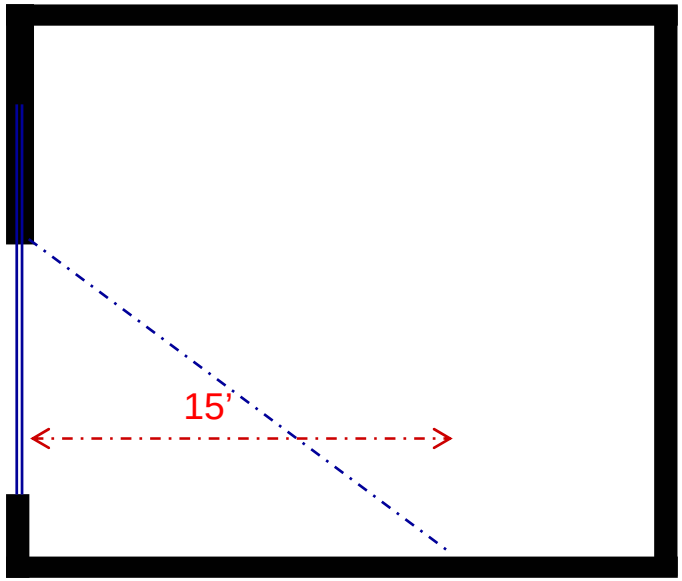
2005 Title 24 Definition of 'Daylit Area'
With Partitions

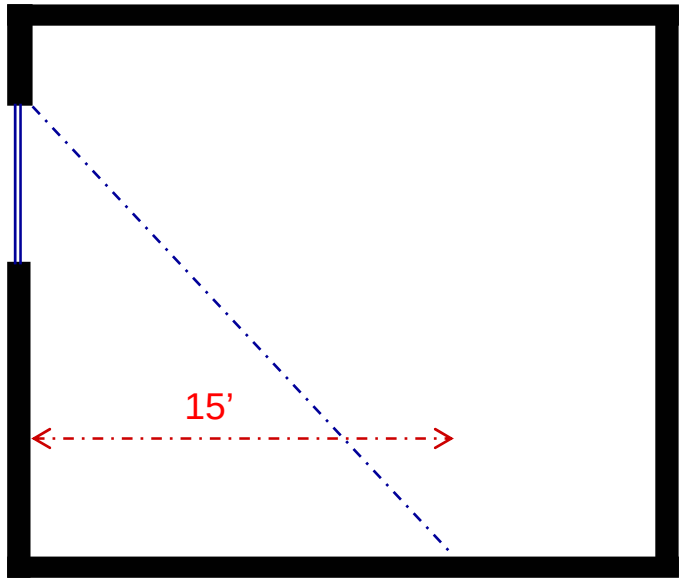
Skylit area under skylights



Proposed 2008 Title 24 Definition of 'Daylit Area'
With Partitions

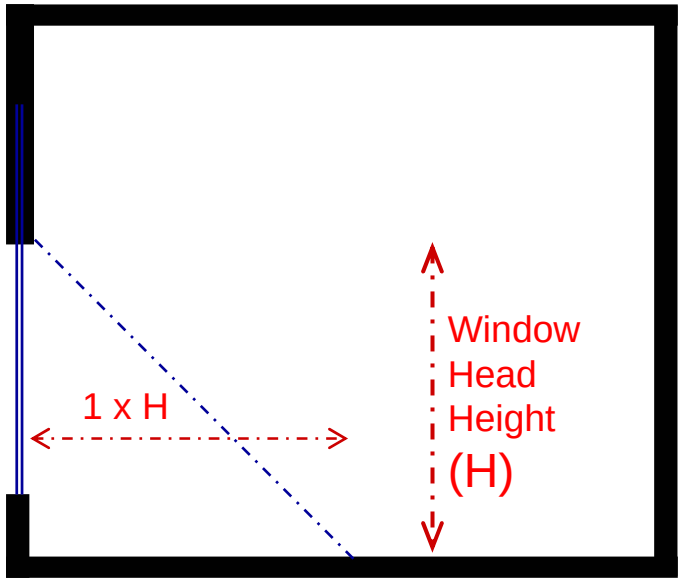
2005 Title 24 – Daylit area illuminated by vertical glazing

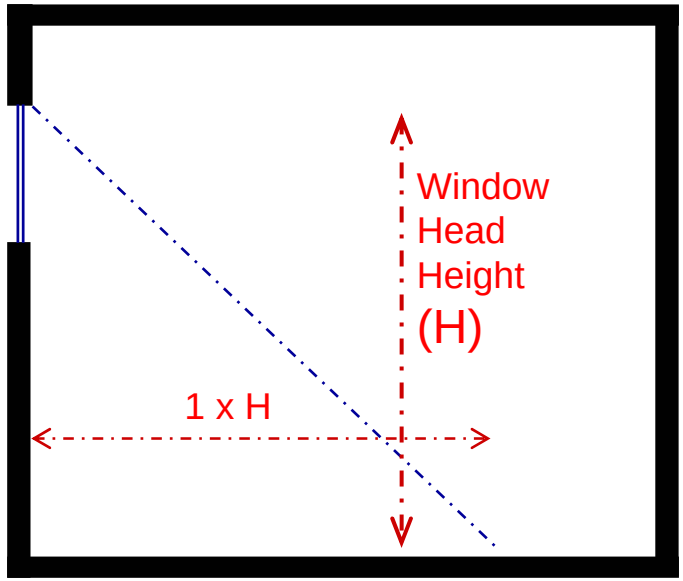




Same Daylit Area Regardless of window and space characteristics

Proposed "Primary Sidelit Area" for 2008 Title 24

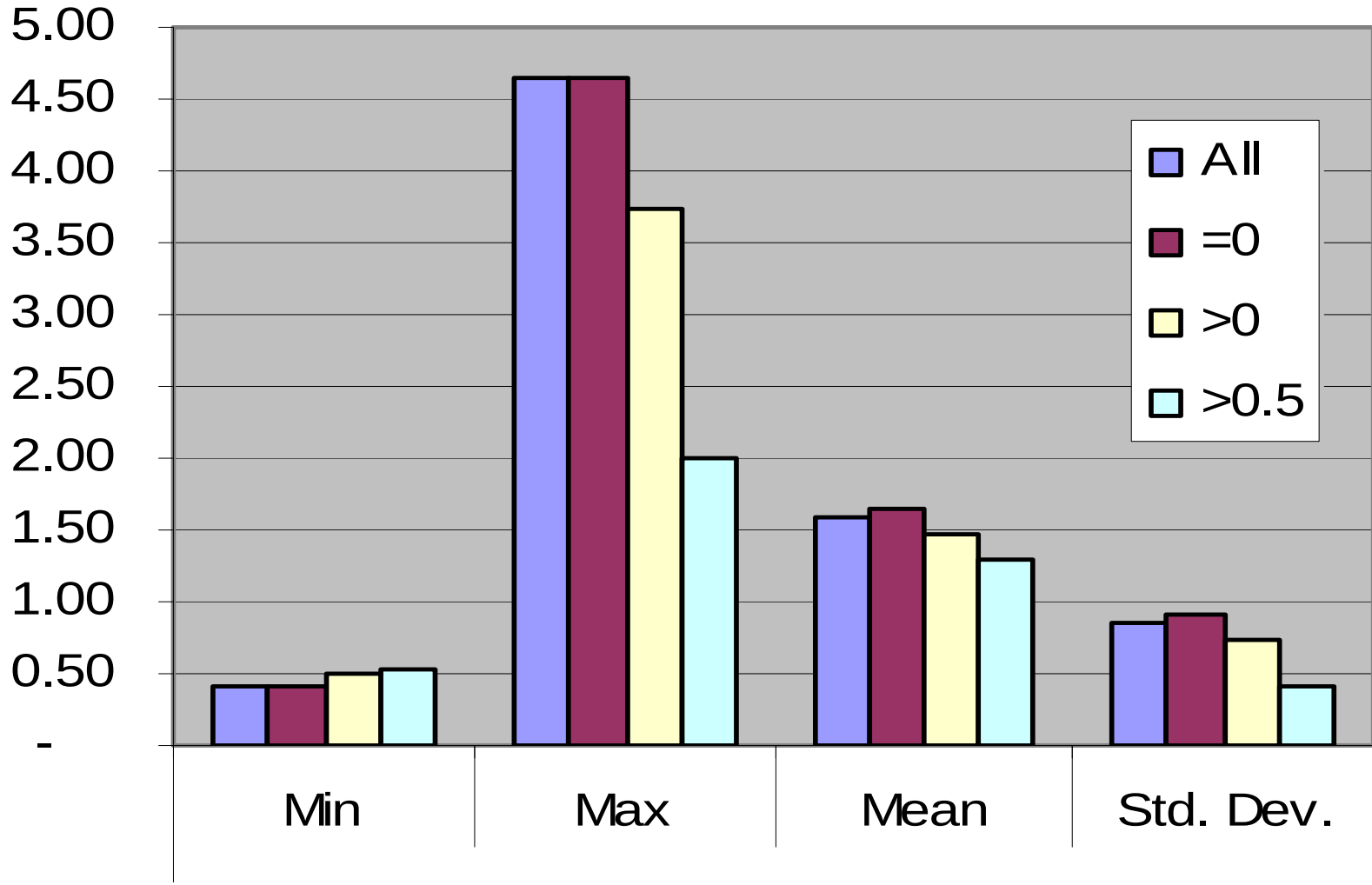




Daylit Area Depth Proportional to Window Head Height

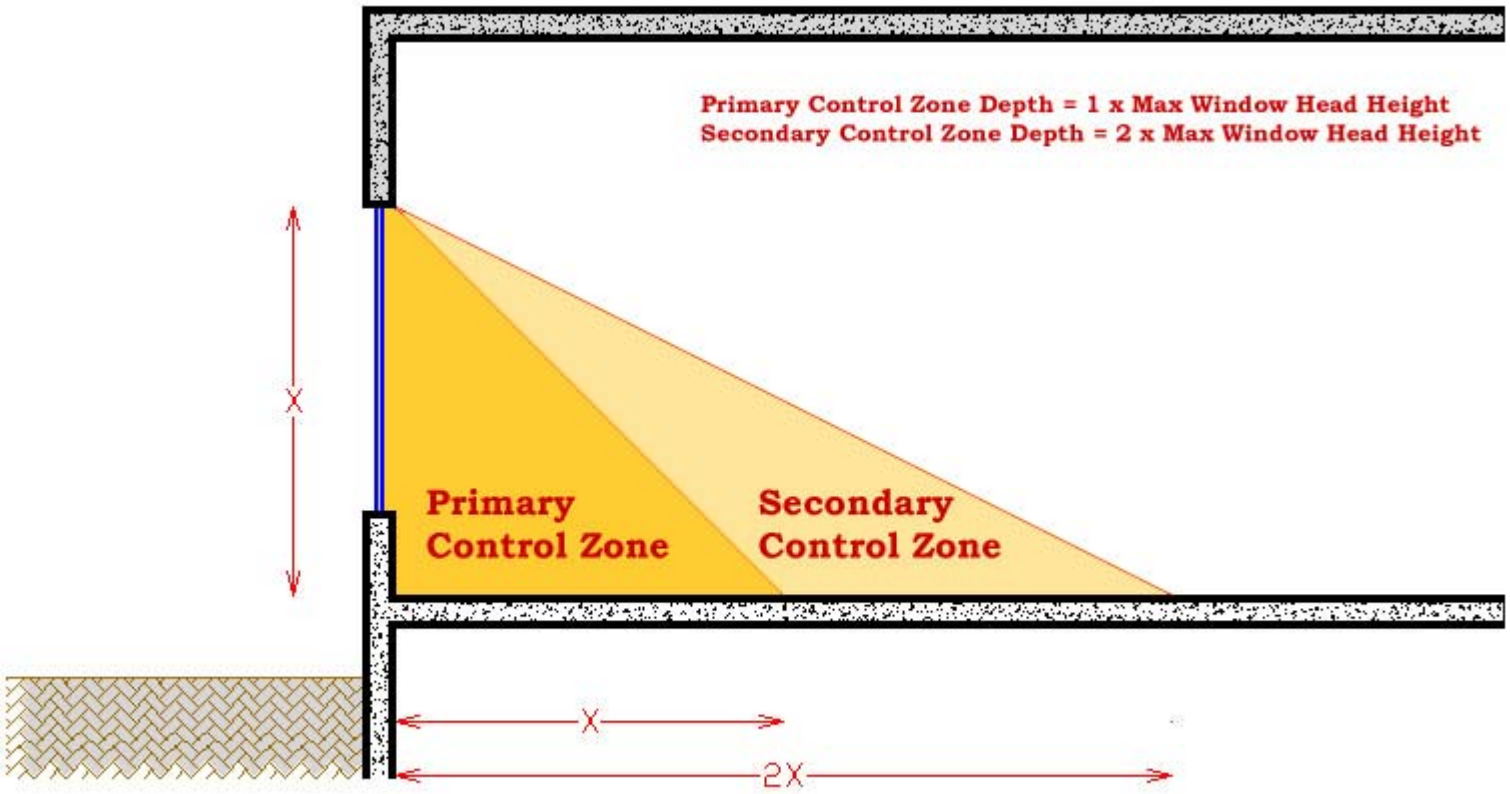
SCE/PG&E/NEEA Sidelighting Photocontrols Study

- Onsite verification of photocontrols performance on 123 spaces in WA, OR, & CA
- Realized Savings Ratio (RSR) = Measured Savings / DOE-2 Predicted Ideal Savings
  - RSR<1 indicates under-performing system
  - RSR>1 indicates over-performing system
- Daylit Control Zone Depth = furthest distance from window where lights photo-controlled
- Control Zone Depth to Window Head Height Ratio



- Spaces with RSR>0.5
  - Max daylit zones depth = 2 times head height
  - Average daylit zone depth = 1.28 x head height

Proposed Daylit Zones – 2008 Title 24



Mandatory Control Requirements in Primary Sidelit Area

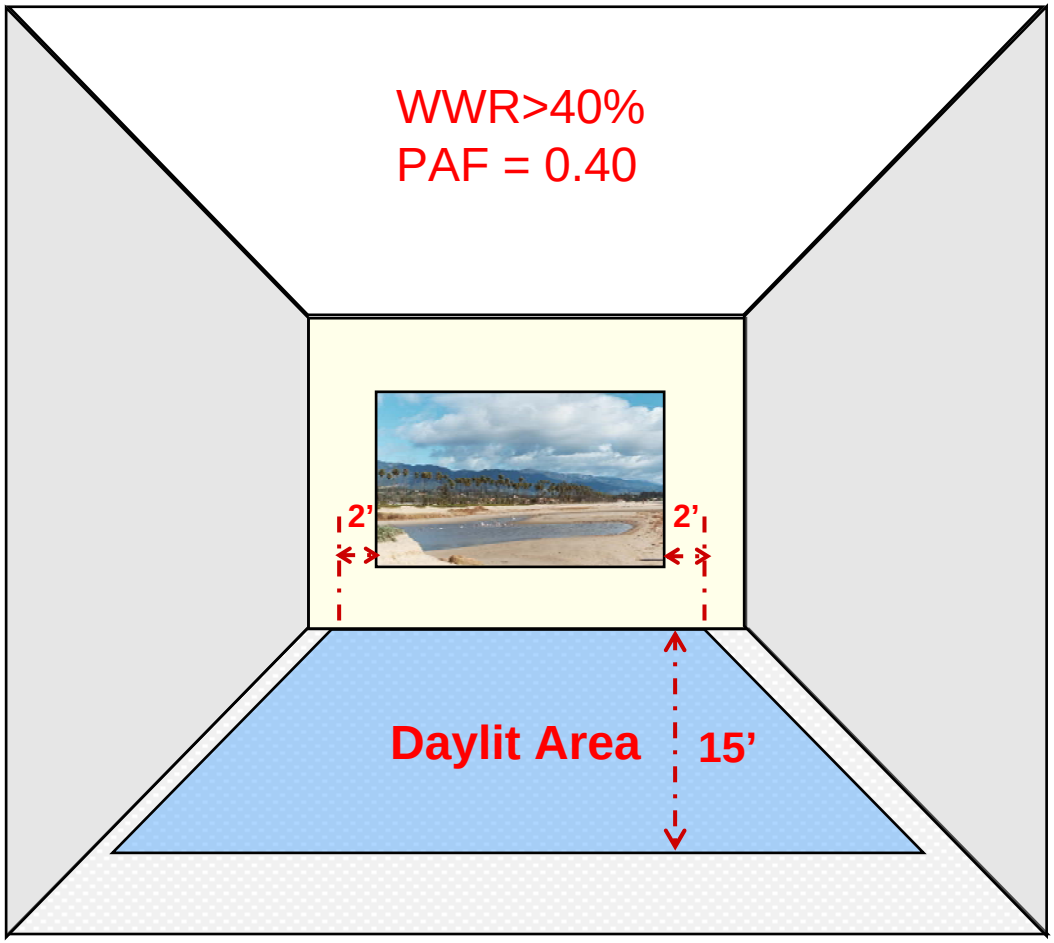
- At least 50% of lights separately circuited in primary control zone
  - A reduction in current zone size until head height > 15’
- When primary control zone exceeds 2,500 sf, multi-level photocontrols required
  - Airport concourses, cafeterias, large spaces
- Exceptions:
  - When LPD< 0.5 W/sf, multi-level control not required
  - Skylight effective aperture > 2.0%, a multi-level astronomical time switch OK
  - When LPD < 0.3 W/sf, controls not required

Cost-effective sidelit controls

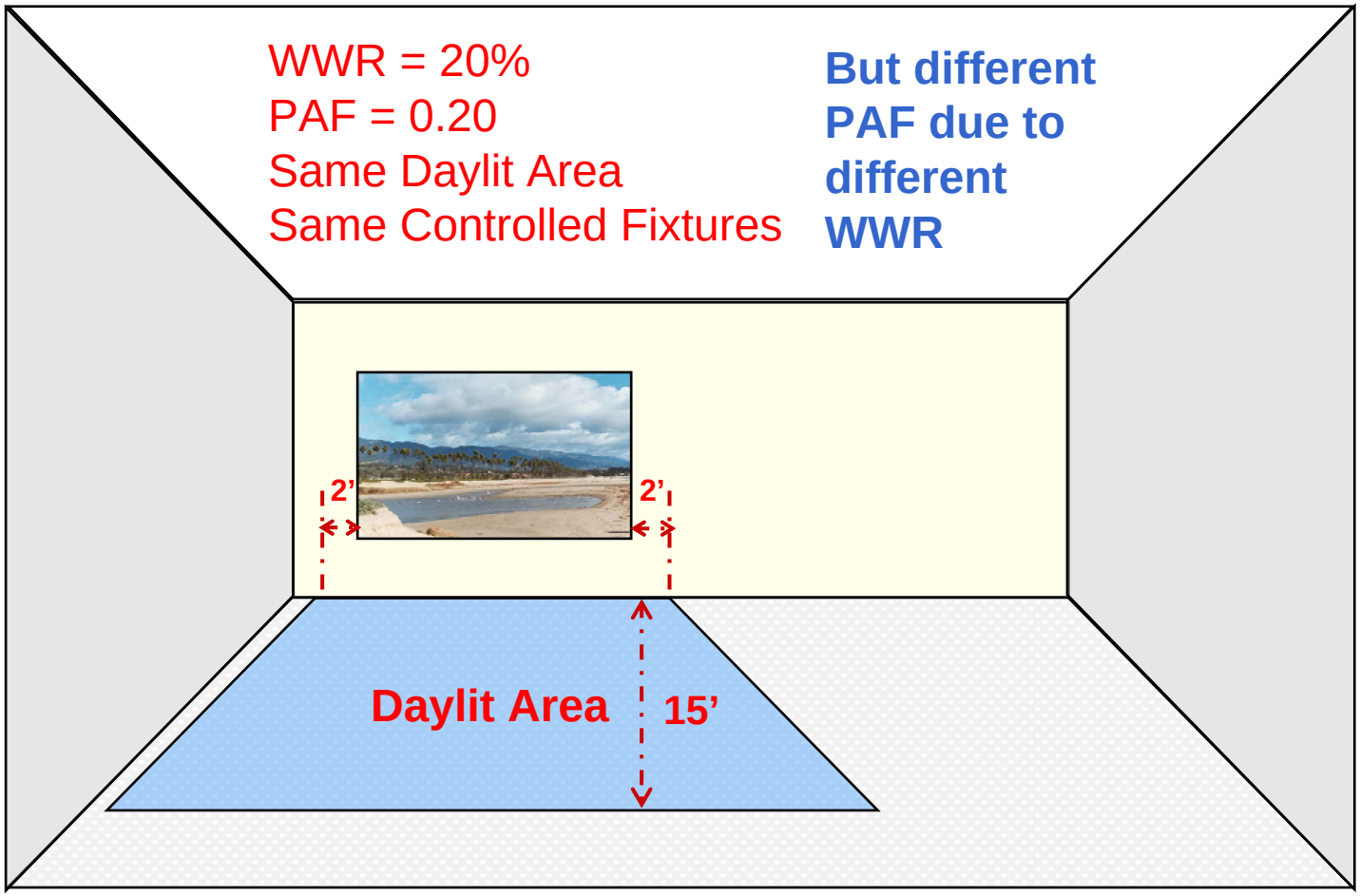
- 2,500 sf space
- < $2,000 controls cost
- Theoretical savings
  - 10% EA $2,975
  - 70% EA $6,700
- B/C ratios:
  - 1.5 to 3.4
- Actual savings depends on commissioning & design

Effective Aperture	Multilevel Controls	
	kWh Savings/sf Daylit Area	TDV Savings/sf Daylilt Area
0.04	0.30	$ 0.53
0.10	0.68	$ 1.19
0.20	1.38	$ 2.46
0.30	1.21	$ 2.12
0.40	1.33	$ 2.32
0.50	1.55	$ 2.72
0.70	1.54	$ 2.68

Current Title 24: High PAF (Power Adjustment Factor) because high WWR



Current Title 24: Low PAF because low WWR



Sidelighting CASE DOE Analysis

Variable	# of Runs per Variable	Parametric Values
Building Type	1	*Open Office (50' x 50')*
Location	2	*CZ 03 (San Francisco), CZ 13 (Fresno)*
Orientation	2	*North Window, South Window*
Ceiling Height*	3	*10.0, 12.0, 20.0*
Window Height*	3	*4.0, 7.0, 12.0, 20.0*
Window/Façade Type*	4	*View Window, Clerestory Window, View + Clerestory Window, Window wall*
Distance from Window/ Max. Window Head Height (DZ Depth/HH ratio)	2	*1.0, 2.0*
Window Visible Light Transmittance	4	*10%, 30%, 50%, 70%*
Lighting Control Strategies	3	*(None, On/Off, Continuous Dimming) setpoint = 50 fc*

* See next slide for details on window size combinations

Sidelighting CASE DOE Analysis

- Window Size Combinations

Ceiling Height	Head Height	View window height	Clerestory Height
10	7		7
10	7	4	
12	12		3
12	12	4	3
12	12		12
20	20		4
20	20	4	4
20	20		20

Effective aperture

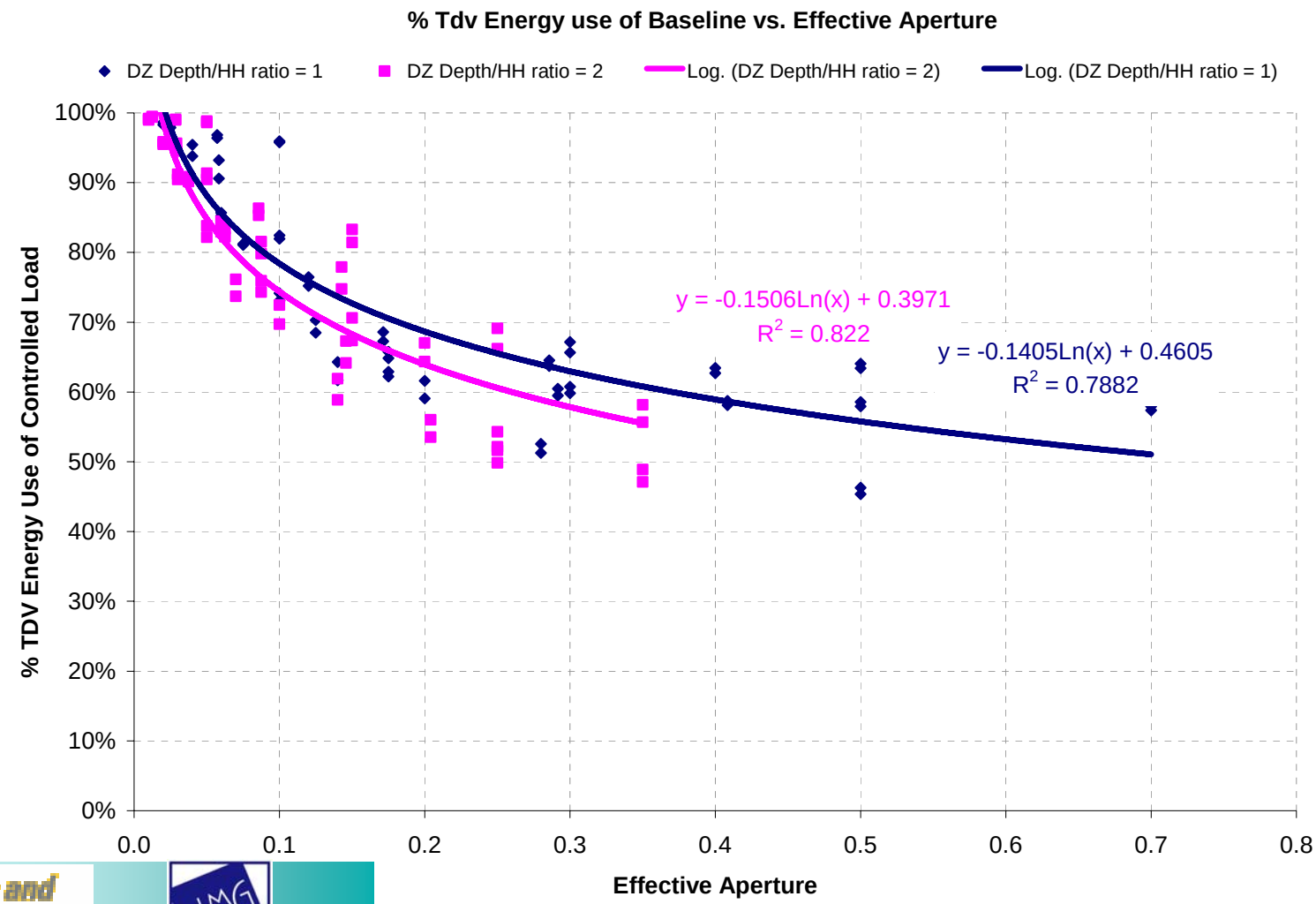
- *EFFECTIVE APERTURE PRIMARY SIDELIT AREA*

$$\text{Primary EA} = \frac{\sum \text{Window Area} \times \text{VT}}{\text{Area of Primary Sidelit Area}}$$

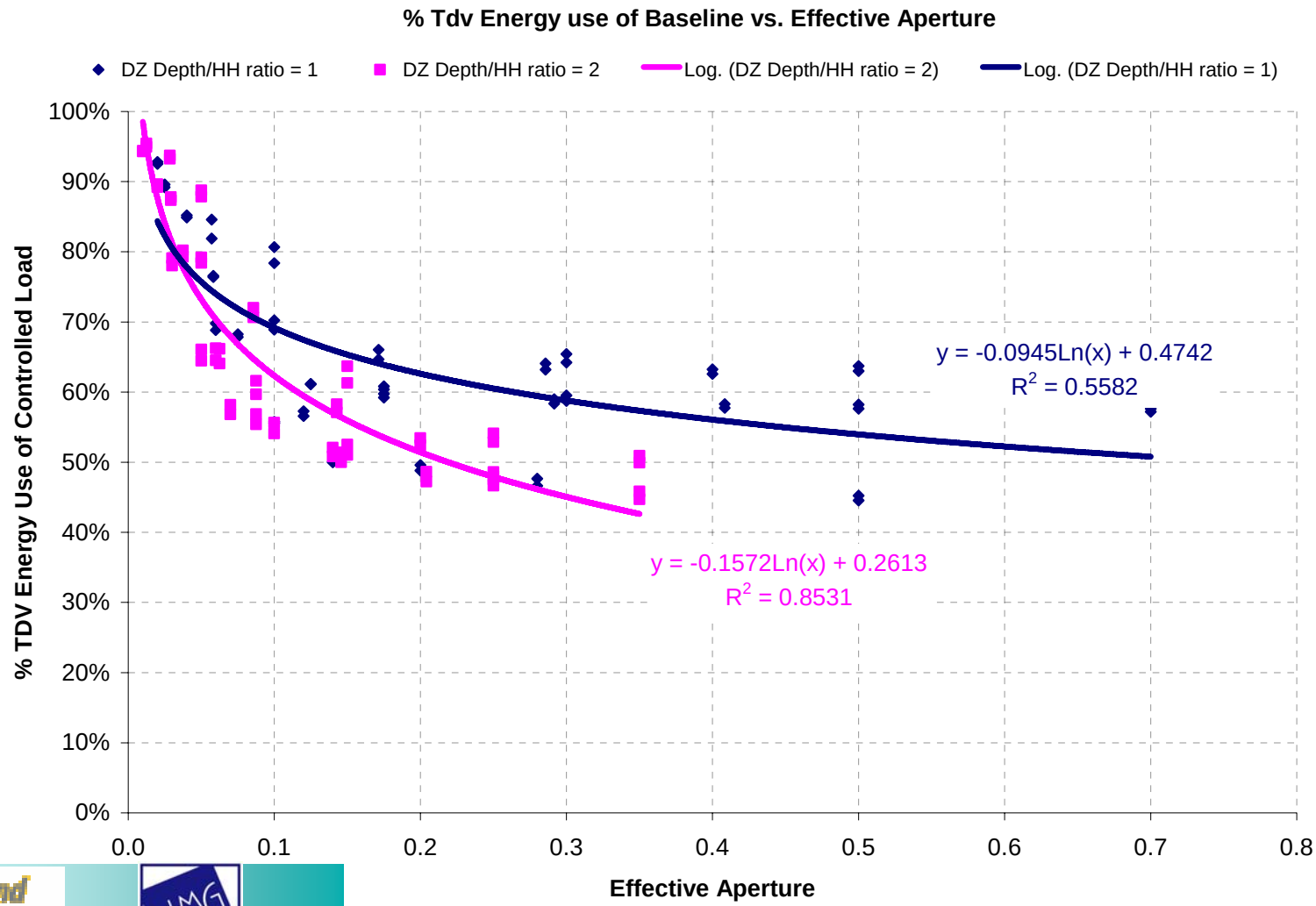
- *EFFECTIVE APERTURE SECONDARY SIDELIT AREA*

$$\text{Secondary EA} = \frac{\sum \text{Window Area} \times \text{VT}}{\text{Primary Sidelit Area} + \text{Secondary Sidelit Area}}$$

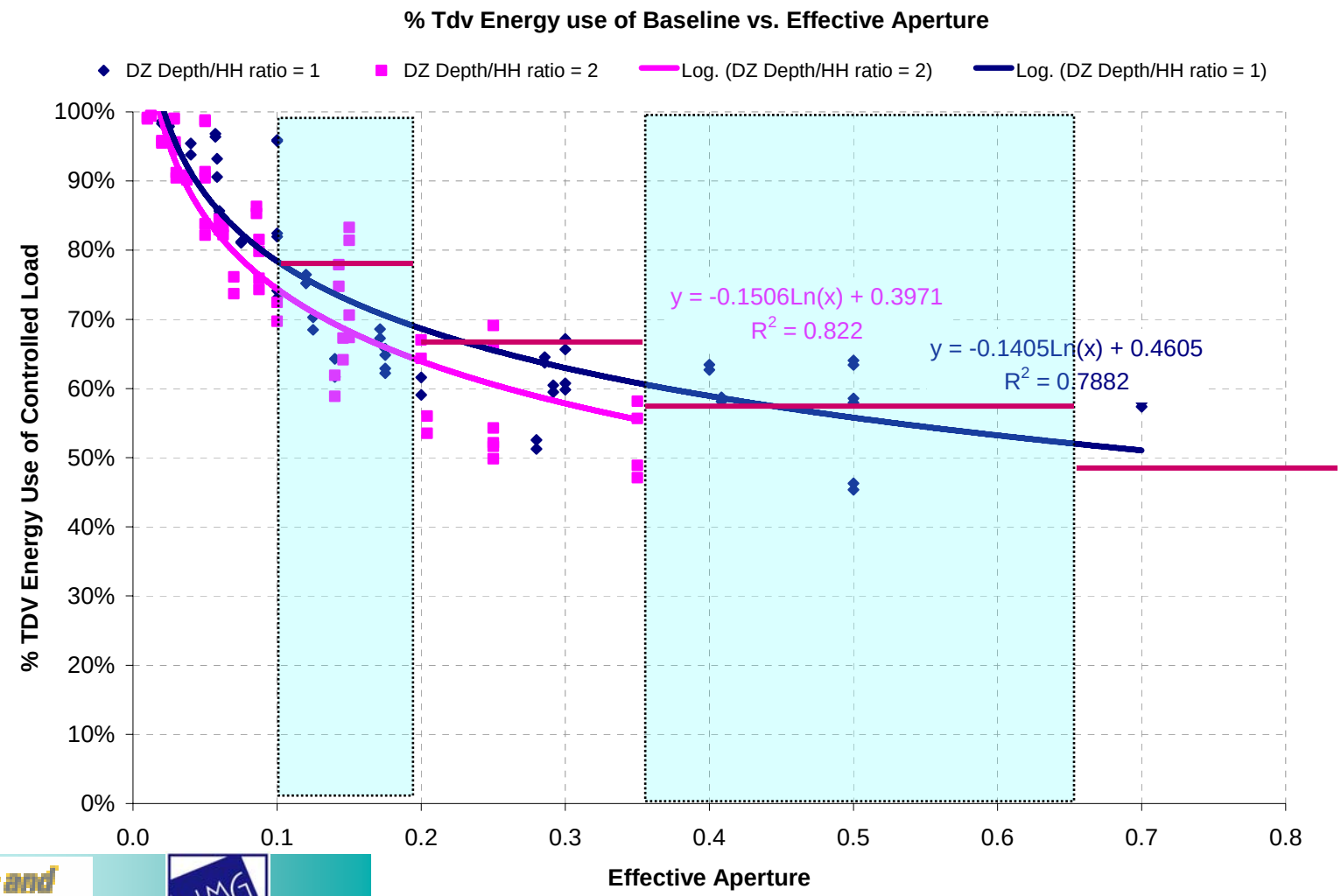
Effective Aperture Good Predictor of Energy Savings (North, CZ 3 & 13, dimming)



Effective Aperture & Lighting Energy Savings (South, CZ 3 & 13, dimming, blinds)



Effective Aperture and Raw PAF's



Sidelit Area Power Adjustment Factors (PAF)

- Raw TDV lighting savings weighted by 58% Realized Savings Ratio (RSR)
  - RSR fraction of actual savings to theoretical
  - 58% RSR for lighting near one head height distance from window
- For both primary and secondary sidelit area

Effective Aperture	Raw PAF	RSR Weighted PAF
< 10%	-	-
10%-20%	0.21	0.12
20%-35%	0.34	0.20
35%-65%	0.43	0.25
> 65%	0.52	0.30

Improved consistency from new sidelit area PAFs

- Both skylighting and sidelighting PAFs based on effective aperture
- Currently two definitions for WWR
  - WWR for fenestration area in Section 143(a) based on entire wall area (includes plenum wall)
  - WWR for sidelighting in Exception 1 to Section 131(c), and Table 146-A based on wall area adjacent to enclosed space (does not include plenum wall)

Skylit Power Adjustment Factors

- Existing PAF – regression equation
  - Based on LPD and skylight effective aperture
  - Hard for bldg inspection to quickly identify if correct factor being used
- Proposed PAF table
  - Hourly calculation of TDV lighting savings from controls
  - Table based on bins of LPD and effective aperture
  - Theoretical savings derated by 70% factor

Controls not lasting as long as lighting

PAF for multi-level controls in skylit area, skylights haze > 90%

General lighting power density (W/sf)	0.6% ≤ EA < 1%	1% ≤ EA < 1.4%	1.4% ≤ EA < 1.8%	1.8% ≤ EA
LPD < 0.7	24%	30%	32%	34%
0.7 ≤ LPD< 1.0	18%	26%	30%	32%
1.0 ≤ LPD < 1.4	12%	22%	26%	28%
1.4 ≤ LPD	8%	20%	24%	28%

Current prescriptive skylighting requirement §143(c)

- Minimum skylight areas and automatic daylighting photocontrols required when
  - Low rise space directly under a roof that is
  - Enclosed space area > 25,000 sf
  - Ceiling height > 15 feet
  - General lighting LPD > 0.5 W/sf
  - In climate temperature zones (CTZs) 2 - 15
- Should this be expanded to more spaces?
  - Was 2005 proposal overly conservative?

Analysis Inputs

- Considered CTZs 3, 7, 10, 12, and 14
- Varied area from 10,000 to 4,000 sf
- SFR varied from 0 to 12%
- LPD from 0.7 to 1.6 W/sf depends upon occupancy
- Double glazed skylights (medium white)
  - visible transmittance of 39%,
  - SHGC of 0.30,
  - U-factor 0.97 Btu/h·°F·sq. ft

Costs

- Energy 15 year present value
  - Electricity (lighting and AC) $1.63/kWh
  - Natural gas (heating) $12.72/therm
- Skylights (installed) approx $25/sf
- Light wells (installed) $1,000 to $1,700
- Photocontrol system $2,500

B/C Analysis: Warehouse 0.7 W/sf, heated only (Lt grey > 1, Dk grey > 1.5, Black > 2)

Case 1: Warehouse, 15' ceiling ht, 1' light well, 0.7 LPD, Heat Only

		10,000 sq.ft		8,000 sq.ft		6,000 sq.ft		4,000 sq.ft	
		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio	
	SFR	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off
CZ 03	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.86	1.21	0.77	1.09	0.66	0.94	0.52	0.73
	2.0%	1.83	1.49	1.70	1.38	1.51	1.23	1.24	1.01
	3.0%	1.77	1.29	1.67	1.21	1.52	1.10	1.29	0.94
	4.0%	1.56	1.10	1.49	1.04	1.37	0.97	1.20	0.84
	5.0%	1.37	0.92	1.32	0.88	1.23	0.83	1.09	0.73
	6.0%	1.21	0.78	1.16	0.75	1.10	0.71	0.98	0.64
	8.0%	0.93	0.56	0.91	0.55	0.86	0.52	0.79	0.48
	10.0%	0.73	0.41	0.71	0.40	0.69	0.38	0.64	0.35
	12.0%	0.58	0.29	0.57	0.28	0.55	0.27	0.51	0.26
	SFR								
CZ 07	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	1.18	1.64	1.07	1.47	0.92	1.27	0.72	0.99
	2.0%	2.49	2.03	2.30	1.88	2.05	1.67	1.69	1.37
	3.0%	2.41	1.81	2.27	1.71	2.07	1.56	1.76	1.32
	4.0%	2.17	1.58	2.07	1.51	1.91	1.39	1.66	1.21
	5.0%	1.94	1.39	1.86	1.33	1.74	1.24	1.54	1.10
	6.0%	1.74	1.22	1.68	1.18	1.58	1.11	1.42	1.00
	8.0%	1.42	0.99	1.38	0.96	1.32	0.91	1.21	0.84
	10.0%	1.19	0.82	1.17	0.80	1.12	0.77	1.04	0.71
	12.0%	1.03	0.69	1.00	0.68	0.97	0.66	0.91	0.62
CZ 10	**SFR**								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	1.08	1.51	0.97	1.36	0.83	1.17	0.65	0.91
	2.0%	2.24	1.76	2.08	1.63	1.85	1.46	1.52	1.20
	3.0%	2.10	1.53	1.98	1.44	1.80	1.31	1.53	1.11
	4.0%	1.86	1.30	1.77	1.24	1.63	1.14	1.42	1.00
	5.0%	1.63	1.11	1.56	1.07	1.46	1.00	1.29	0.88
	6.0%	1.44	0.96	1.39	0.93	1.31	0.88	1.17	0.79
	8.0%	1.15	0.74	1.11	0.72	1.06	0.69	0.97	0.63
	10.0%	0.93	0.58	0.91	0.57	0.88	0.55	0.81	0.51
	12.0%	0.78	0.46	0.76	0.46	0.73	0.44	0.69	0.41

B/C Analysis: Warehouse 0.7 W/sf, heated only (continued)

Case 1: Warehouse, 15' ceiling ht, 1' light well, 0.7 LPD, Heat Only									
		10,000 sq.ft		***8,000 sq.ft***		***6,000 sq.ft***		***4,000 sq.ft***	
		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio	
	SFR	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off
CZ 12	**SFR**								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.87	**1.23**	0.79	**1.11**	0.68	0.95	0.53	0.74
	2.0%	**1.85**	**1.45**	**1.72**	**1.34**	**1.53**	**1.20**	**1.26**	0.98
	3.0%	**1.74**	**1.24**	**1.64**	**1.17**	**1.49**	**1.06**	**1.27**	0.90
	4.0%	**1.52**	**1.01**	**1.44**	0.96	**1.33**	0.89	**1.16**	0.77
	5.0%	**1.30**	0.83	**1.25**	0.79	**1.17**	0.74	**1.03**	0.66
	6.0%	**1.12**	0.67	**1.08**	0.65	**1.02**	0.61	0.91	0.55
	8.0%	0.83	0.43	0.81	0.42	0.77	0.40	0.70	0.37
	10.0%	0.61	0.27	0.59	0.26	0.57	0.25	0.53	0.23
	12.0%	0.45	0.15	0.44	0.14	0.42	0.14	0.40	0.13
CZ 14	**SFR**								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	**1.34**	**1.80**	**1.21**	**1.62**	**1.04**	**1.39**	0.81	**1.09**
	2.0%	**2.57**	**2.00**	**2.38**	**1.85**	**2.12**	**1.65**	**1.74**	**1.35**
	3.0%	**2.38**	**1.66**	**2.24**	**1.57**	**2.04**	**1.43**	**1.73**	**1.21**
	4.0%	**2.03**	**1.39**	**1.94**	**1.33**	**1.79**	**1.23**	**1.56**	**1.07**
	5.0%	**1.76**	**1.17**	**1.69**	**1.12**	**1.58**	**1.05**	**1.40**	0.93
	6.0%	**1.54**	0.99	**1.48**	0.96	**1.40**	0.90	**1.25**	0.81
	8.0%	**1.19**	0.74	**1.16**	0.72	**1.10**	0.69	**1.01**	0.63
	10.0%	0.95	0.57	0.93	0.55	0.89	0.53	0.83	0.49
	12.0%	0.77	0.44	0.76	0.43	0.73	0.42	0.69	0.39

B/C Analysis: Conditioned (proxy for comfort) warehouse 0.7 W/sf

Case 5: Warehouse, 15' ceiling ht, 1' light well, 0.7 LPD, AC and Heat

		10,000 sq.ft		8,000 sq.ft		6,000 sq.ft		4,000 sq.ft	
		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio	
	SFR	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off	2 Level + Off	2/3 on/off
CZ 03	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.64	0.95	0.57	0.85	0.49	0.73	0.38	0.57
	2.0%	**1.66**	**1.33**	**1.54**	**1.24**	**1.37**	**1.10**	**1.13**	0.90
	3.0%	**1.60**	**1.12**	**1.51**	**1.05**	**1.37**	0.96	**1.17**	0.81
	4.0%	**1.39**	0.88	**1.32**	0.84	**1.22**	0.77	**1.06**	0.67
	5.0%	**1.16**	0.69	**1.11**	0.66	**1.04**	0.62	0.92	0.55
	6.0%	0.97	0.52	0.94	0.50	0.88	0.48	0.79	0.43
	8.0%	0.67	0.28	0.65	0.27	0.62	0.26	0.57	0.24
	10.0%	0.45	0.10	0.44	0.10	0.42	0.10	0.39	0.09
	12.0%	0.28	(0.03)	0.27	(0.03)	0.27	(0.03)	0.25	(0.03)
CZ 10	**SFR**								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.63	**1.09**	0.57	0.98	0.49	0.85	0.38	0.66
	2.0%	**1.88**	**1.41**	**1.75**	**1.31**	**1.56**	**1.17**	**1.28**	0.96
	3.0%	**1.72**	**1.02**	**1.62**	0.96	**1.47**	0.87	**1.25**	0.74
	4.0%	**1.33**	0.66	**1.27**	0.63	**1.17**	0.58	**1.02**	0.50
	5.0%	**1.01**	0.37	0.96	0.36	0.90	0.33	0.80	0.30
	6.0%	0.73	0.15	0.70	0.14	0.66	0.13	0.59	0.12
	8.0%	0.31	(0.19)	0.30	(0.18)	0.29	(0.17)	0.26	(0.16)
	10.0%	0.02	(0.42)	0.01	(0.41)	0.01	(0.39)	0.01	(0.36)
	12.0%	(0.21)	(0.59)	(0.20)	(0.57)	(0.20)	(0.56)	(0.18)	(0.52)
CZ 12	**SFR**								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.48	0.86	0.44	0.78	0.37	0.67	0.29	0.52
	2.0%	**1.53**	**1.10**	**1.42**	**1.02**	**1.27**	0.91	**1.04**	0.75
	3.0%	**1.33**	0.76	**1.25**	0.71	**1.14**	0.65	0.97	0.55
	4.0%	**1.02**	0.41	0.97	0.39	0.89	0.36	0.78	0.31
	5.0%	0.71	0.14	0.68	0.13	0.64	0.12	0.56	0.11
	6.0%	0.45	(0.08)	0.44	(0.08)	0.41	(0.07)	0.37	(0.07)
	8.0%	0.06	(0.41)	0.05	(0.40)	0.05	(0.38)	0.05	(0.35)
	10.0%	(0.23)	(0.64)	(0.23)	(0.63)	(0.22)	(0.60)	(0.20)	(0.56)
	12.0%	(0.45)	(0.81)	(0.44)	(0.79)	(0.43)	(0.77)	(0.40)	(0.72)
CZ 14	**SFR**								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.67	**1.23**	0.60	**1.11**	0.52	0.96	0.40	0.75
	2.0%	**1.98**	**1.34**	**1.84**	**1.24**	**1.64**	**1.10**	**1.34**	0.91
	3.0%	**1.61**	0.76	**1.52**	0.72	**1.38**	0.65	**1.18**	0.55
	4.0%	**1.10**	0.29	**1.05**	0.28	0.97	0.25	0.84	0.22
	5.0%	0.66	(0.08)	0.63	(0.07)	0.59	(0.07)	0.52	(0.06)
	6.0%	0.32	(0.36)	0.31	(0.35)	0.29	(0.33)	0.26	(0.30)
	8.0%	(0.21)	(0.78)	(0.20)	(0.75)	(0.19)	(0.72)	(0.18)	(0.66)
	10.0%	(0.57)	(1.06)	(0.56)	(1.03)	(0.53)	(0.99)	(0.50)	(0.92)
	12.0%	(0.83)	(1.26)	(0.82)	(1.23)	(0.79)	(1.19)	(0.74)	(1.12)

NOT cost-effective below 8,000 sf for all controls and climates

Retail 15’ open ceiling versus 12’ dropped ceiling with light wells

Case 7: Retail, 15' ceiling ht, 1' light well, 1.6 LPD, AC and Heat

		10,000 sq.ft		8,000 sq.ft		6,000 sq.ft		4,000 sq.ft	
		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio	
	SFR	2/3 on/off	Dim 20%	2/3 on/off	Dim 20%	2/3 on/off	Dim 20%	2/3 on/off	Dim 20%
CZ 03	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	1.00	2.38	0.90	2.14	0.77	1.84	0.60	1.44
	2.0%	2.76	3.52	2.56	3.26	2.28	2.90	1.87	2.38
	3.0%	3.03	3.44	2.85	3.24	2.60	2.95	2.21	2.51
	4.0%	2.88	3.09	2.74	2.94	2.53	2.72	2.20	2.36
	5.0%	2.58	2.71	2.48	2.60	2.32	2.43	2.05	2.15
	6.0%	2.29	2.38	2.21	2.29	2.08	2.16	1.87	1.94
	8.0%	1.83	1.85	1.78	1.79	1.69	1.71	1.55	1.57
	10.0%	1.46	1.46	1.43	1.42	1.37	1.37	1.27	1.27
	12.0%	1.18	1.16	1.15	1.14	1.11	1.10	1.04	1.03
	SFR								
CZ 07	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	1.17	2.79	1.06	2.52	0.91	2.16	0.71	1.69
	2.0%	3.27	4.06	3.03	3.76	2.70	3.35	2.22	2.75
	3.0%	3.60	3.89	3.39	3.67	3.09	3.34	2.62	2.84
	4.0%	3.23	3.40	3.07	3.23	2.84	2.99	2.47	2.60
	5.0%	2.86	2.92	2.74	2.80	2.56	2.62	2.27	2.32
	6.0%	2.48	2.51	2.39	2.42	2.25	2.28	2.02	2.05
	8.0%	1.88	1.87	1.83	1.81	1.74	1.73	1.60	1.59
	10.0%	1.42	1.41	1.39	1.37	1.34	1.32	1.24	1.23
	12.0%	1.09	1.07	1.06	1.04	1.03	1.01	0.96	0.95
CZ 10	SFR								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	1.00	2.54	0.90	2.29	0.78	1.97	0.61	1.54
	2.0%	2.94	3.68	2.72	3.41	2.43	3.04	1.99	2.50
	3.0%	3.11	3.40	2.92	3.20	2.67	2.92	2.26	2.48
	4.0%	2.64	2.82	2.51	2.69	2.32	2.49	2.02	2.16
	5.0%	2.22	2.30	2.12	2.21	1.99	2.06	1.76	1.83
	6.0%	1.83	1.87	1.77	1.80	1.67	1.70	1.50	1.52
	8.0%	1.20	1.21	1.17	1.18	1.12	1.12	1.02	1.03
	10.0%	0.76	0.75	0.74	0.73	0.71	0.70	0.66	0.65
	12.0%	0.42	0.41	0.42	0.40	0.40	0.39	0.38	0.36
CZ 12	SFR								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.91	2.38	0.82	2.15	0.71	1.85	0.55	1.44
	2.0%	2.69	3.46	2.49	3.21	2.22	2.86	1.82	2.35
	3.0%	2.78	3.22	2.62	3.03	2.38	2.76	2.02	2.34
	4.0%	2.54	2.72	2.41	2.58	2.23	2.39	1.94	2.08
	5.0%	2.13	2.24	2.04	2.14	1.91	2.01	1.69	1.78
	6.0%	1.74	1.83	1.68	1.76	1.59	1.66	1.42	1.49
	8.0%	1.17	1.19	1.14	1.16	1.08	1.10	0.99	1.01
	10.0%	0.72	0.72	0.71	0.70	0.68	0.68	0.63	0.63
	12.0%	0.38	0.36	0.37	0.36	0.36	0.35	0.34	0.32

Case 8: Retail, 12' ceiling ht, 4'+Splays light well, 1.6 LPD, AC and Heat

		10,000 sq.ft		8,000 sq.ft		6,000 sq.ft		4,000 sq.ft	
		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio		15 year B/C Ratio	
	SFR	2/3 on/off	Dim 20%	2/3 on/off	Dim 20%	2/3 on/off	Dim 20%	2/3 on/off	Dim 20%
CZ 03	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.15	0.38	0.15	0.37	0.15	0.36	0.14	0.34
	2.0%	0.55	0.70	0.54	0.69	0.52	0.67	0.50	0.64
	3.0%	0.70	0.80	0.69	0.78	0.67	0.77	0.64	0.73
	4.0%	0.74	0.80	0.73	0.79	0.72	0.77	0.69	0.74
	5.0%	0.72	0.76	0.72	0.75	0.70	0.74	0.68	0.71
	6.0%	0.69	0.71	0.68	0.70	0.67	0.69	0.64	0.67
	8.0%	0.61	0.61	0.60	0.61	0.59	0.60	0.57	0.58
	10.0%	0.52	0.52	0.51	0.51	0.51	0.51	0.49	0.49
	12.0%	0.44	0.44	0.44	0.43	0.43	0.43	0.42	0.42
	SFR								
CZ 07	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.19	0.45	0.19	0.44	0.18	0.43	0.17	0.40
	2.0%	0.65	0.81	0.64	0.79	0.62	0.77	0.59	0.74
	3.0%	0.83	0.90	0.82	0.89	0.80	0.87	0.77	0.83
	4.0%	0.83	0.88	0.82	0.87	0.81	0.85	0.77	0.81
	5.0%	0.80	0.82	0.79	0.81	0.78	0.80	0.75	0.77
	6.0%	0.74	0.75	0.73	0.74	0.72	0.73	0.70	0.71
	8.0%	0.62	0.62	0.61	0.61	0.61	0.60	0.59	0.58
	10.0%	0.51	0.50	0.50	0.50	0.49	0.49	0.48	0.47
	12.0%	0.41	0.40	0.40	0.40	0.40	0.39	0.39	0.38
CZ 10	SFR								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.16	0.40	0.15	0.40	0.15	0.39	0.14	0.37
	2.0%	0.58	0.73	0.58	0.72	0.56	0.70	0.53	0.67
	3.0%	0.72	0.79	0.71	0.78	0.69	0.76	0.66	0.73
	4.0%	0.68	0.73	0.67	0.72	0.66	0.70	0.63	0.68
	5.0%	0.62	0.65	0.62	0.64	0.60	0.63	0.58	0.60
	6.0%	0.55	0.56	0.54	0.55	0.53	0.54	0.52	0.53
	8.0%	0.40	0.40	0.39	0.40	0.39	0.39	0.38	0.38
	10.0%	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.25
	12.0%	0.16	0.15	0.16	0.15	0.16	0.15	0.15	0.15
CZ 12	SFR								
	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.0%	0.14	0.38	0.14	0.37	0.13	0.36	0.13	0.34
	2.0%	0.53	0.69	0.52	0.68	0.51	0.66	0.48	0.63
	3.0%	0.64	0.74	0.63	0.73	0.62	0.72	0.59	0.69
	4.0%	0.65	0.70	0.64	0.69	0.63	0.68	0.60	0.65
	5.0%	0.60	0.63	0.59	0.62	0.58	0.61	0.56	0.59
	6.0%	0.52	0.55	0.52	0.54	0.51	0.53	0.49	0.51
	8.0%	0.39	0.39	0.38	0.39	0.38	0.38	0.36	0.37
	10.0%	0.26	0.26	0.25	0.25	0.25	0.25	0.24	0.24
	12.0%	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13

Conclusions

- Possible to exceed 1.5 B/C ratio in most areas greater than 8,000 sf, ceiling > 15 ft
- Presence of light wells renders system not cost-effective
- Section 143(c) criteria should be changed to:
  - floor area > 8,000 sf,
  - ceiling ht > 15 ft
  - general lighting LPD > 0.5 W/sf

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