

Fenestration Codes and Standards

Charles Eley, FAIA, PE

A Brief History

A Brief History

1971

1972



Oil Embargo

1973

1974



Governor Jerry Brown

1975

ASHRAE approves Standard 90-1975
Maximum Overall U-factor
Maximum OTTV

1976

1977

California Energy Commission created



First "Star Wars"

1978

CEC adopts first generation standards

1979

First Generation Prescriptive Criteria

FIGURE 2-53B

MAXIMUM U_{ow} VALUES FOR WALLS, HEATING

$U \leq 0.41$ for San Francisco

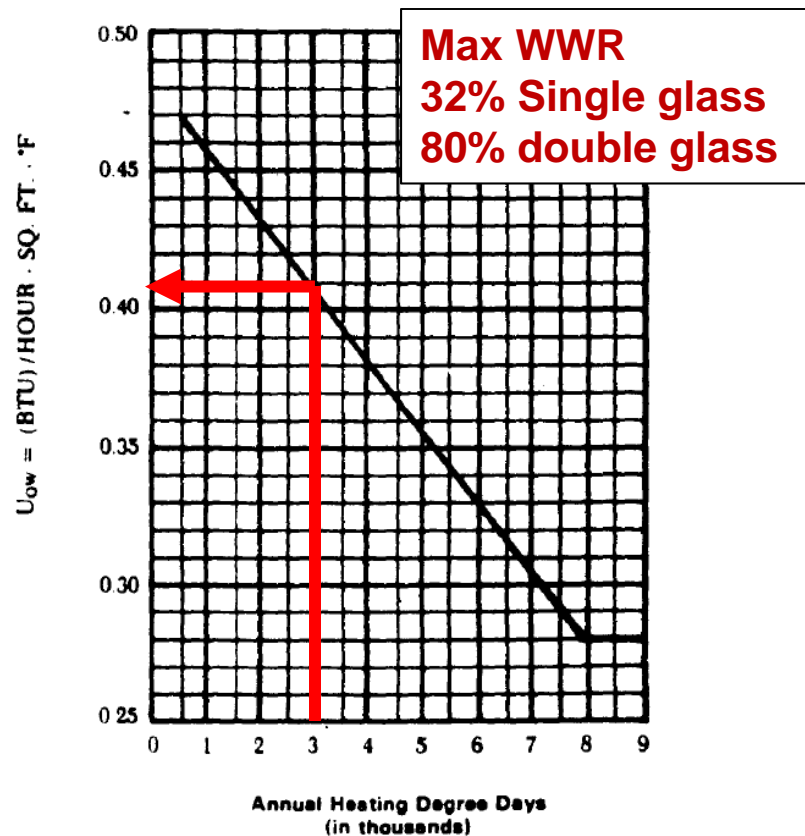
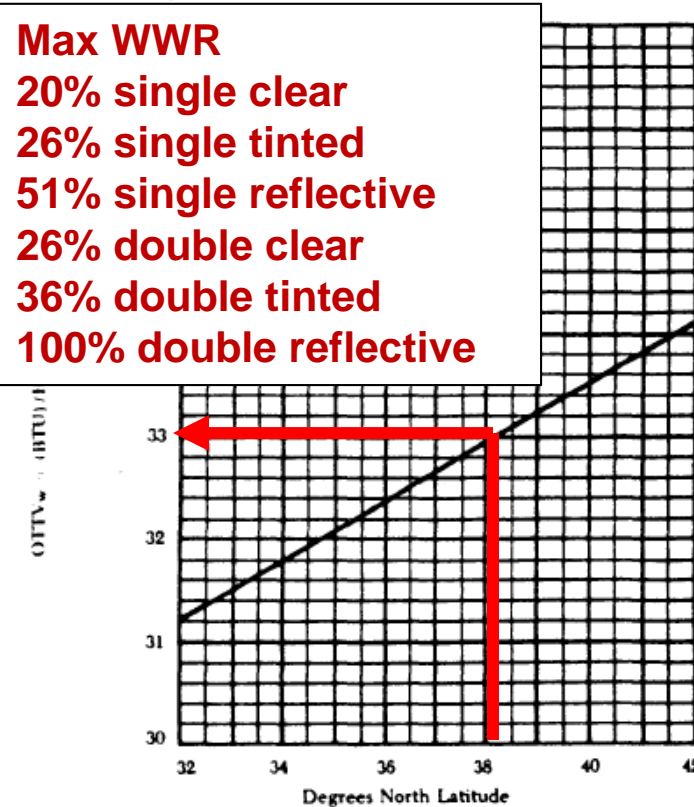


FIGURE 2-53E

OVERALL THERMAL TRANSFER VALUES FOR WALLS, COOLING

OTTV ≤ 33 for San Francisco



A Brief History



"Chariots of Fire" wins Best Picture

1980

1981

1982

1983

1984



Space shuttle Challenger

1985

1986

1987

Second generation standards were adopted for offices and retail

1988



Loma Prieta Earthquake

1989

ASHRAE updates Standard 90.1

California Prescriptive Requirements

TABLE 2-53V3
ALTERNATIVE COMPONENT PACKAGES FOR CLIMATE ZONE #03
FOR LOW-RISE OFFICE BUILDINGS

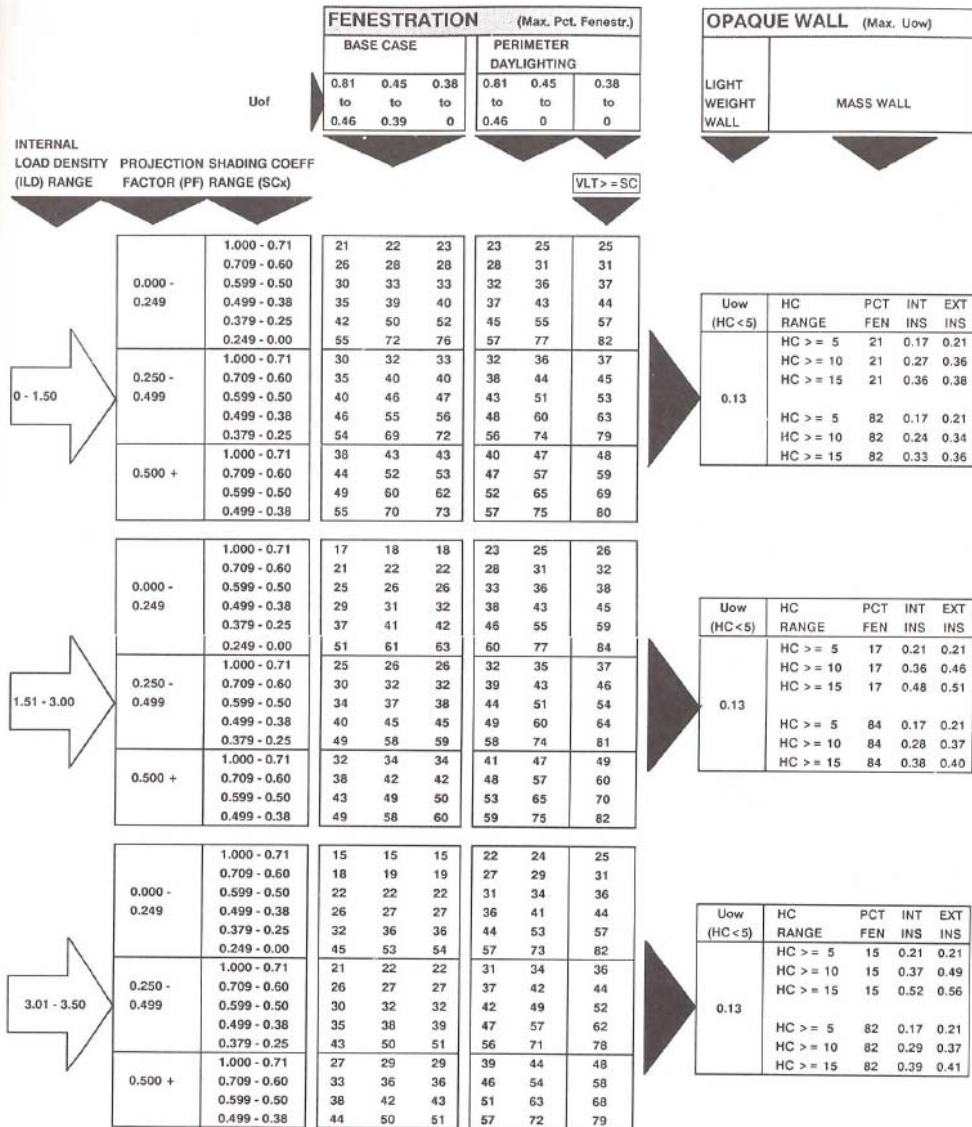
Component	PACKAGE					
	A	B	C	D	E	F
OPAQUE ENVELOPE						
Minimum Roof Total R-Value (R_t)	9.52	9.52	12.51	9.50	9.50	12.40
Minimum Opaque Wall Total R-Value (R_t) (one of the following):						
Heat Capacity [Btu/°F/ft ²]						
0.0 - 3.99	7.52	7.52	3.00	11.00	11.00	2.90
4.0 - 9.99	7.57	7.57	3.00	9.90	9.90	2.50
10.0 - 14.99	6.35	6.35	2.30	7.00	7.00	1.90
15.0 - 19.99	5.97	5.97	1.55	4.90	4.90	1.60
20.0 or more	3.56	3.56	1.40	3.20	3.20	1.50
Minimum Suspended Exterior Floor Total R-Value (R_t)	9.50	9.50	9.50	9.50	9.50	9.50
GLAZING						
Maximum Allowed Total Vertical Glazing (one of the following):	[Note: See Section 2-5342(b)2.]					
Shading Coefficient						
1.00 - 0.72	22%	22%	22%	24%	42%	24%
0.71 - 0.66	25%	25%	25%	30%	52%	30%
0.65 - 0.56	26%	26%	26%	31%	57%	31%
0.55 - 0.36	32%	32%	32%	33%	60%	33%
0.35 - 0.01	22%	42%	42%	42%	62%	42%
See Section 2-5342(b)5, for overhang equivalents.						

U-factor ≤ 0.65

Standards expressed in terms of maximum glazing area

A Brief History

ASHRAE Standard 90.1-1989

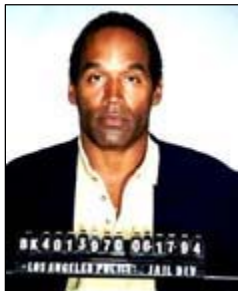


Both California and ASHRAE defined fenestration standards in terms of maximum glazing area

A Brief History



Gulf War



O.J. Simpson

1990

National Fenestration Rating Council



1991

1992

CEC simplifies the nonresidential standards which consider glass area to be neutral unless $WWR > 40\%$

1993

1994

Paradym Shift

1995

Energy codes start to focus on fenestration performance instead of glazing area

1996

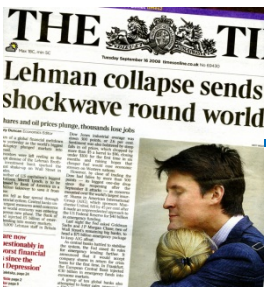
1997

1998

1999

ASHRAE Standard 90.1-1999 follows an approach similar to California

A Brief History



2000

2001

2002

2003

2004

2005

2006

2007

2008

2009

California 2001
ASHRAE 90.1-2001

ASHRAE 90.1-2004

California 2005

ASHRAE 90.1-2007

California 2008

California and
ASHRAE play a
game of leapfrog

C

A Brief History



Hurricane Sandy

2010 — ASHRAE 90.1-2010

2011

2012

2013 — ASHRAE 90.1-2013
California 2013

2014 — California 2013 becomes effective
ASHRAE 90.1 Addendum BM out for public review

2015

2016

2017

2018

2019



A Brief History

2020 — New residences to be zero net-energy

2021

2022

2023

2024

2025

2026

2027

2028

2029



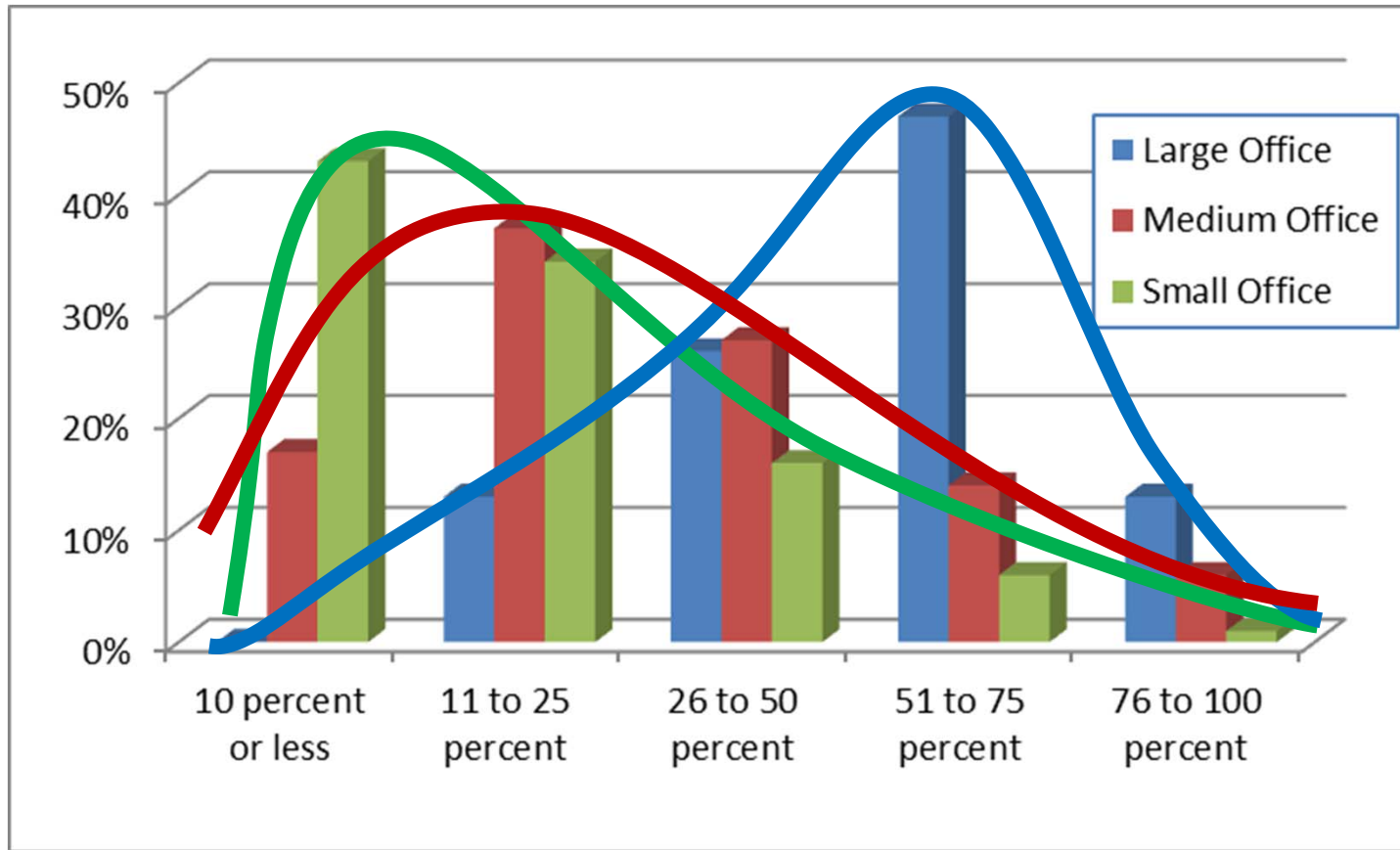
— New commercial buildings to be zero net energy



Typical Window Wall Ratios

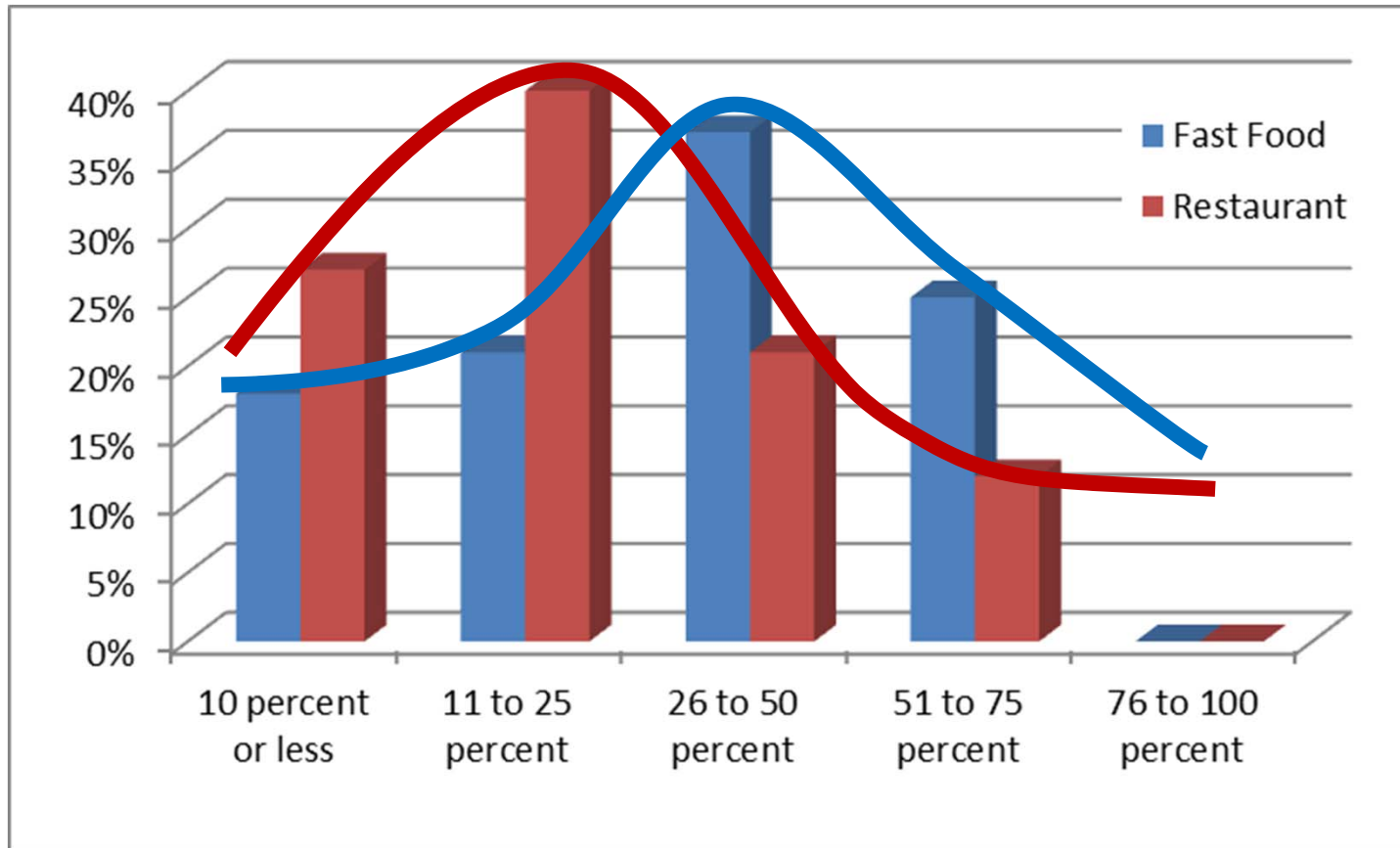
Typical Window Wall Ratios

Offices



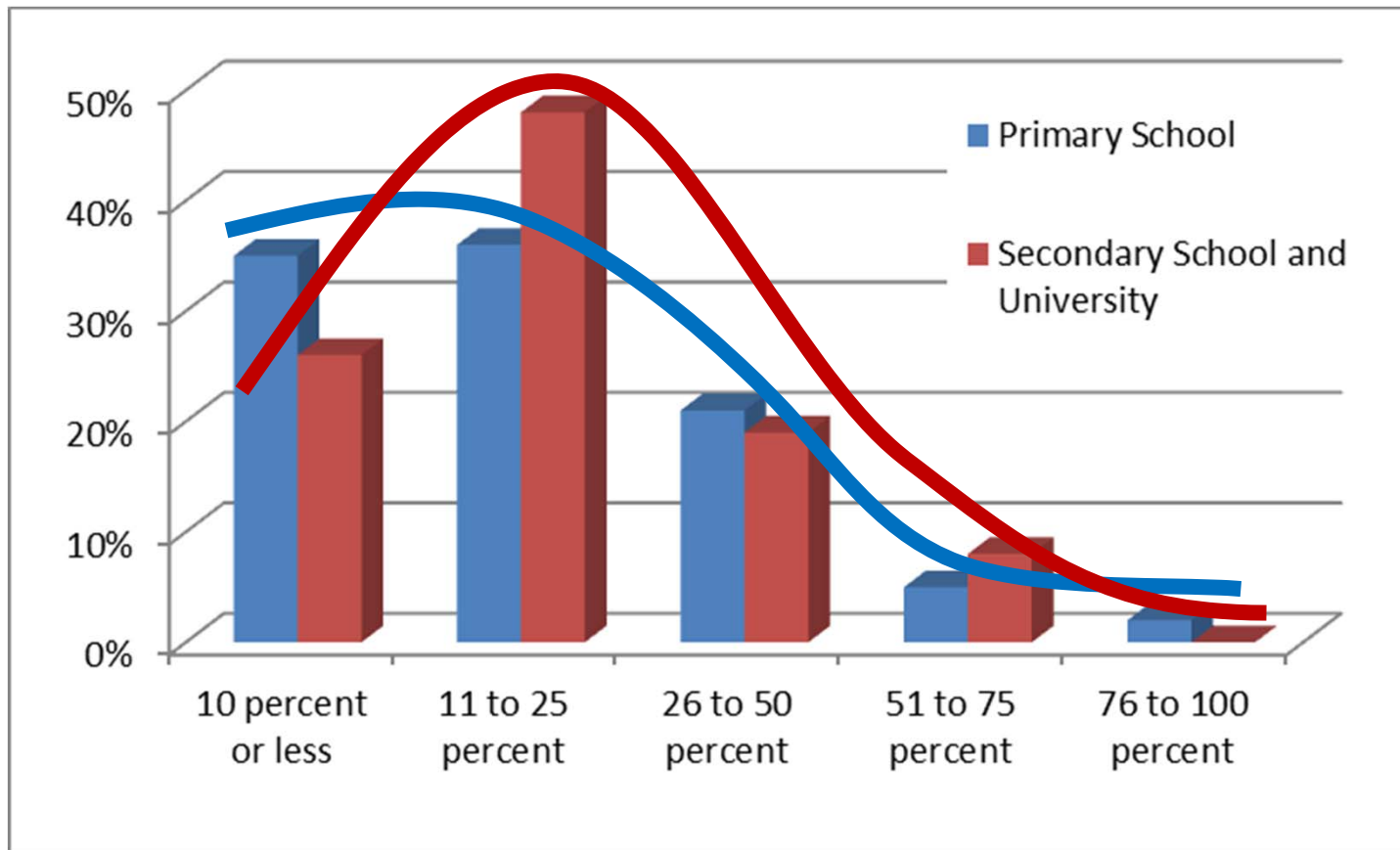
Typical Window Wall Ratios

Restaurants



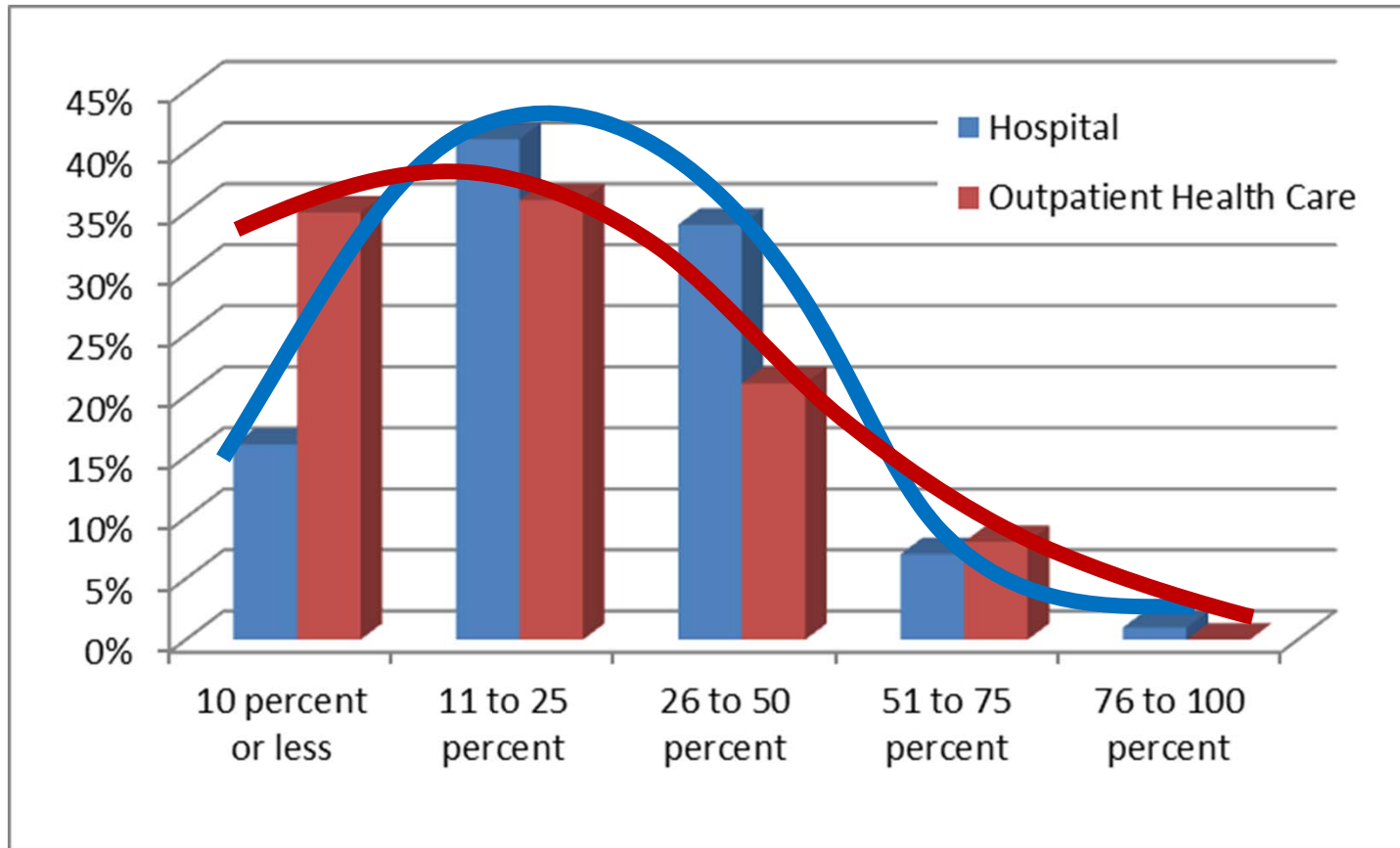
Typical Window Wall Ratios

Schools



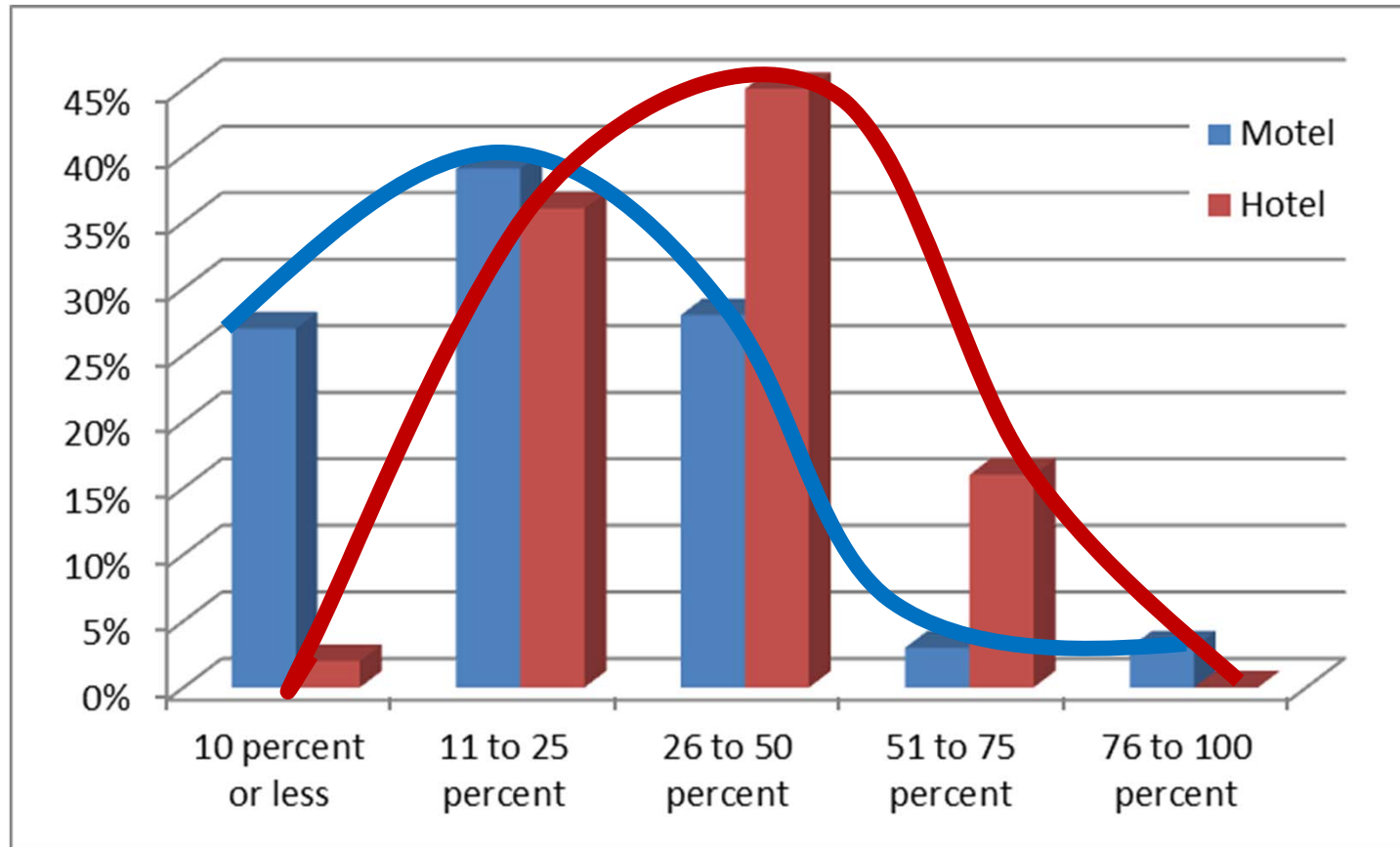
Typical Window Wall Ratios

Healthcare



Typical Window Wall Ratios

Lodging



Typical Window Wall Ratios

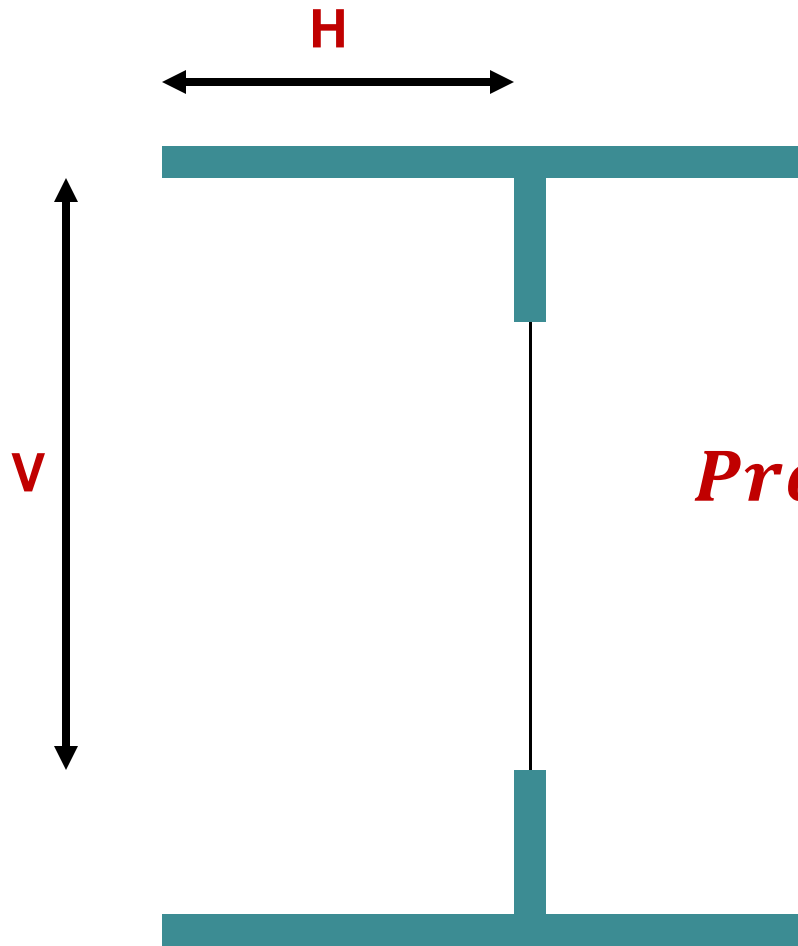
Data from CBECS 2003 (Commercial Building Energy Conservation Survey)

Reference Number	Reference Building Type	10 percent or less	11 to 25 percent	26 to 50 percent	51 to 75 percent	76 to 100 percent	Average WWR
1	Large Office	0%	13%	26%	47%	13%	54%
2	Medium Office	17%	37%	27%	14%	6%	31%
3	Small Office	43%	34%	16%	6%	1%	19%
4	Warehouse	92%	6%	1%	0%	0%	6%
5	Stand-alone Retail	66%	27%	6%	1%	0%	11%
6	Strip Mall	NA	NA	NA	NA	NA	NA
7	Primary School	35%	36%	21%	5%	2%	22%
8	Secondary School and University	26%	48%	19%	8%	0%	22%
9	Grocery Store	81%	19%	0%	0%	0%	7%
10	Fast Food	18%	21%	37%	25%	0%	34%
11	Restaurant	27%	40%	21%	12%	0%	24%
12	Hospital	16%	41%	34%	7%	1%	27%
13	Outpatient Health Care	35%	36%	21%	8%	0%	21%
14	Motel	27%	39%	28%	3%	3%	24%
15	Hotel	2%	36%	45%	16%	0%	34%

Source: Analysis of Building Envelope Construction in 2003 CBECS, Dave Winiarski, et. al., June 2007, **PNNL-20380**

Orientation and Shading

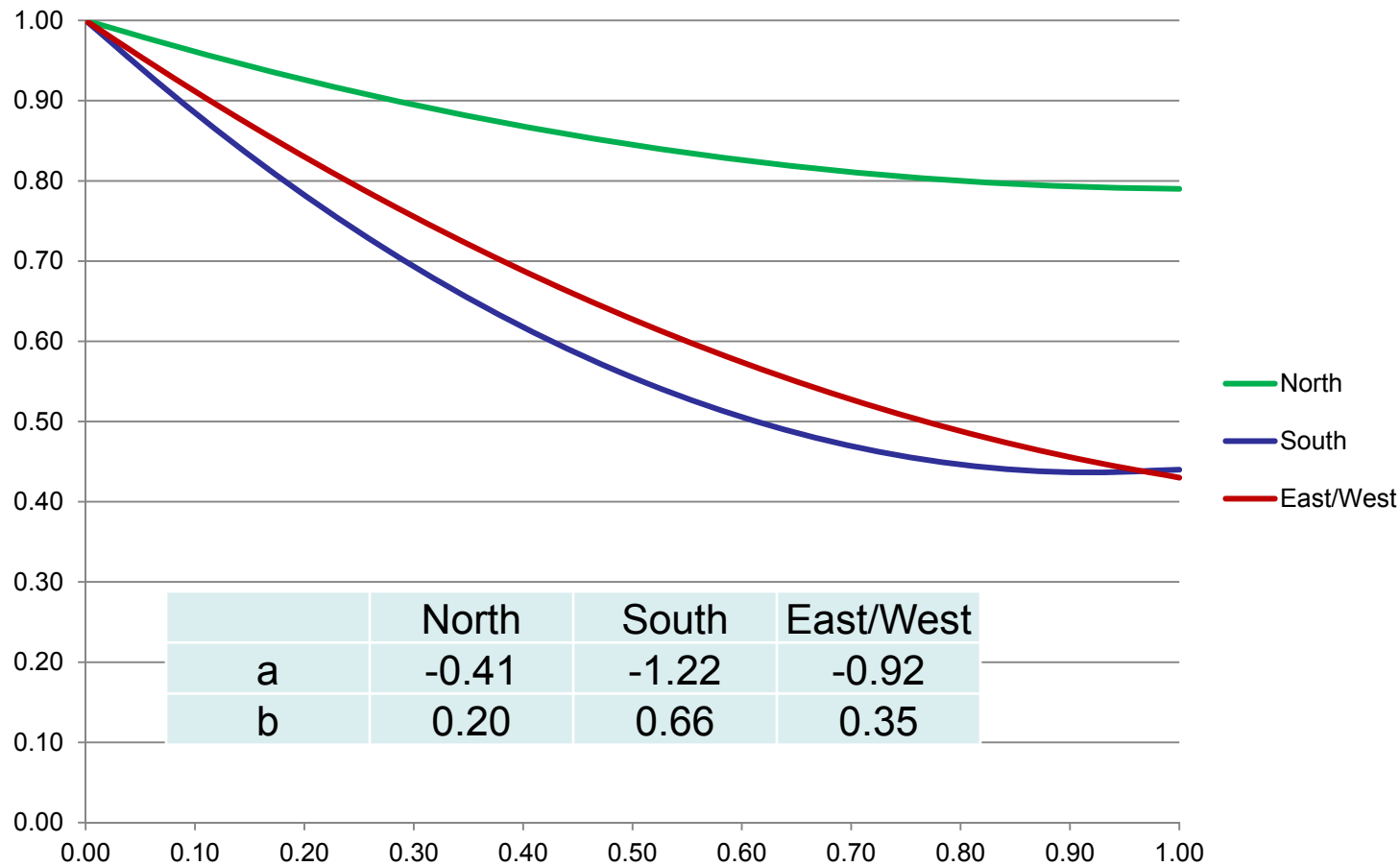
Projection Factor



$$\text{Projection Factor (PF)} = \frac{H}{V}$$

Relative Solar Heat Gain

$$RSHG = SHGC \times [1 - a \times PF + b \times PF^2]$$



California Orientation Restrictions

- West facing glazing as well as total glazing is limited to 40%

ASHRAE 2013 Orientation Restrictions

$$A_w \leq \frac{A_t}{4} \quad \text{AND} \quad A_e \leq \frac{A_t}{4}$$

OR

$$A_e \times SHGC_e \leq \frac{A_t \times SHGC_c}{4}$$

AND

$$A_w \times SHGC_w \leq \frac{A_t \times SHGC_c}{4}$$

Exceptions

- Windows with permanent shading (overhangs or louvers)
- Buildings shaded by existing structures
- Alterations
- Facades with 20% WWR or less

Special Case for Street Level Display

- California allows a minimum of six feet times the display perimeter
- ASHRAE allows 75% WWR, but requires overhang with $PF \geq 0.50$

Progression of Prescriptive Requirements

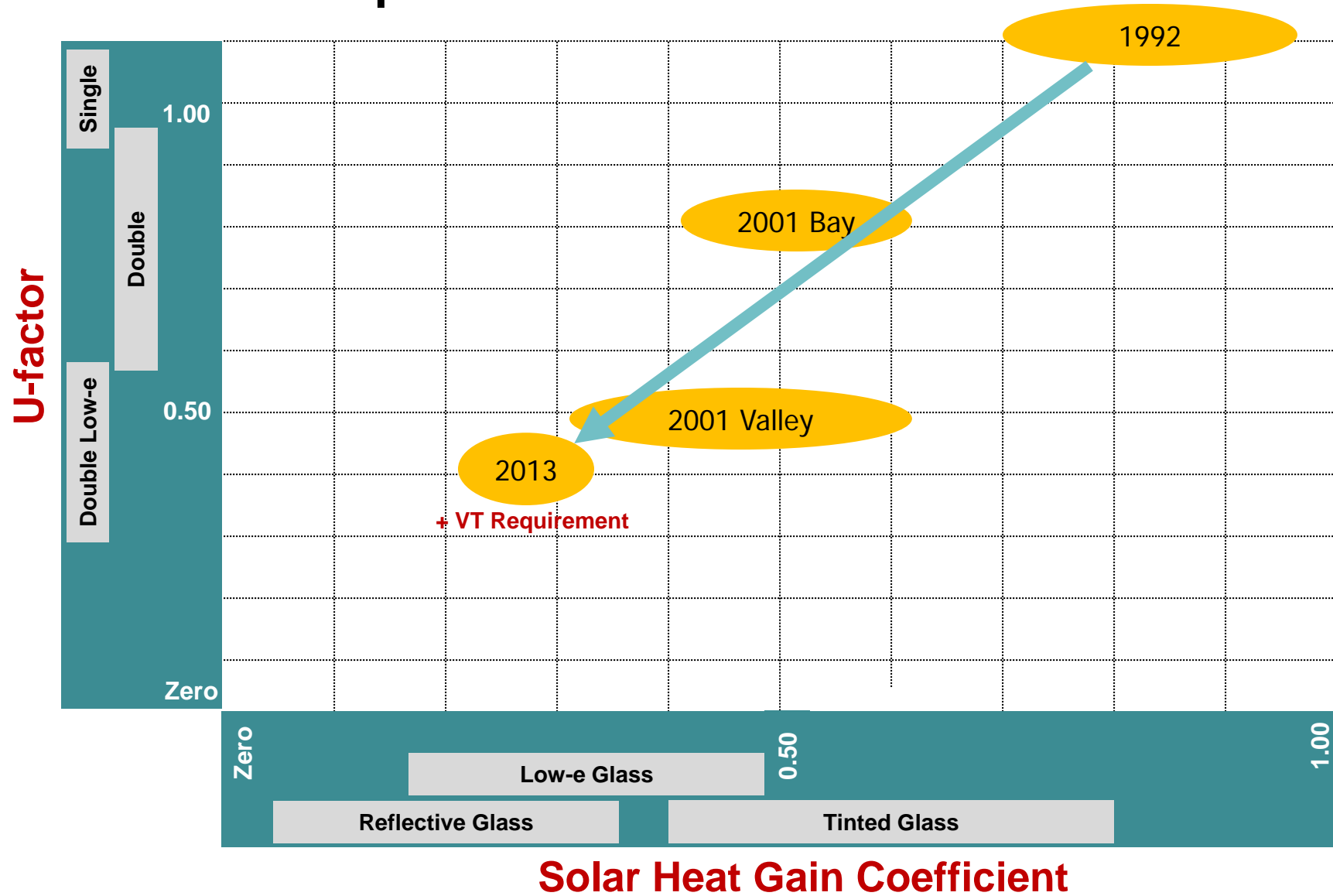
Progression of Prescriptive Requirements

California Requirements

Code	CZ	U-factor	SHGC			VT
California 1992	Bay	1.23	0.94 North 0.71 All			No requirement
	Valley	0.72	0.88 North 0.57 All			
California 2001	Bay	0.81	WWR	All	North	No requirement
			10%	0.61	0.61	
			20%	0.55	0.61	
			30%	0.41	0.61	
	Valley	0.49	WWR	All	North	
			10%	0.47	0.61	
			20%	0.36	0.51	
			30%	0.36	0.47	
			40%	0.31	0.47	
California 2013	All	All Climates 0.36 Fixed 0.46 Operable 0.41 Curtainwall 0.45 Glass doors	All Climates 0.25 Fixed 0.22 Operable 0.26 Curtainwall 0.23 Glass doors			All Climates 0.42 Fixed 0.32 Operable 0.46 Curtainwall 0.17 Glass doors

Progression of Prescriptive Requirements

California Requirements



Fenestration Products that Comply with California 2013

Frame	Outer Lite	2 nd Surface Coating	Spacer	Gas	Inner Lite	4 th Surface Coating	Fixed Window NFRC Ratings ¹		
							U-factor	SHGC	VT
Thermal break	Clear	Triple silver	Aluminum	Argon	Clear	Uncoated	0.35	0.25	0.53
Thermal break	Clear	Triple silver	Aluminum	Air	Clear	Pyrolytic	0.34	0.24	0.49
Thermal break	Clear	Triple silver	Aluminum	Argon	Clear	Pyrolytic	0.31	0.23	0.49
Thermal break	Green	Triple silver	Aluminum	Argon	Clear	Uncoated	0.35	0.22	0.45
Thermal break	Green	Triple silver	Aluminum	Air	Clear	Pyrolytic	0.34	0.21	0.42
Thermal break	Green	Triple silver	Aluminum	Argon	Clear	Pyrolytic	0.31	0.21	0.42
Thermal break	Blue-green	Double silver	Aluminum	Argon	Clear	Uncoated	0.35	0.23	0.45
Thermal break	Dark green	Double silver	Aluminum	Argon	Clear	Uncoated	0.35	0.23	0.45
Thermal break	Green	Double silver	Aluminum	Argon	Clear	Pyrolytic	0.32	0.25	0.48
Thermal break	High-performance	Double silver	Aluminum	Argon	Clear	Uncoated	0.35	0.23	0.46
Thermal break	High-performance	Double silver	Aluminum	Air	Clear	Pyrolytic	0.34	0.22	0.42
Thermal break	High-performance	Double silver	Aluminum	Argon	Clear	Pyrolytic	0.32	0.22	0.42
Thermal break	High-performance	Single silver	Aluminum	Air	Clear	Pyrolytic	0.35	0.25	0.46
Thermal break	High-performance	Single silver	Aluminum	Argon	Clear	Pyrolytic	0.33	0.25	0.46

Progression of Prescriptive Requirements

Options with Shading

Path	Frame	Outter Lite	2 nd Surface Coating	Spacer	Gas	Inner Lite	4 th Surface Coating	Fixed Window NFRC Ratings ¹		
								U-factor	SHGC	VT
RSHG ²	Minimum 3" overhang									
	Thermal break	Green	Double silver	Aluminum	Air	Clear	Pyrolytic	0.34	0.26	0.48
	Minimum 9" overhang									
	Thermal break	Green	Double silver	Aluminum	Argon	Clear	Uncoated	0.35	0.27	0.52
	Thermal break	High-performance	Single silver	Mild steel	Argon	Clear	Uncoated	0.36	0.27	0.5
	Minimum 3' overhang									
	Thermal break	Green	Single silver	Aluminum	Argon	Clear	Pyrolytic	0.33	0.31	0.51
	Thermal break	Clear	Double silver	Aluminum	Air	Clear	Pyrolytic	0.34	0.31	0.55
	Thermal break	Clear	Double silver	Aluminum	Argon	Clear	Pyrolytic	0.32	0.31	0.55
	Thermal break	Green	Single silver	Aluminum	Air	Clear	Pyrolytic	0.35	0.31	0.51
Area Weighted ³	The following view window...									
	Thermal break	Bronze	Double silver	Hybrid steel	Argon	Clear	Uncoated	0.34	0.23	0.36
	...with the following clerestory window									
	Thermal break	Clear	Double silver	Aluminum	Argon	Clear	Uncoated	0.35	0.33	0.6
	Thermal break	Clear	Double silver	Hybrid steel	Argon	Clear	Pyrolytic	0.3	0.31	0.59
Thermal break	Clear	Triple silver	Aluminum	Argon	Clear	Uncoated	0.34	0.25	0.53	

Component Examples

Category	Type
Coatings	<u>Triple silver</u> Viracon VNE1-63, Cardinal LoE-366, PPG Solarban 70XL, Guardian SuperNeutral 62
	<u>Double silver</u> Viracon VE1-2M, Cardinal LoE-272, PPG Solarban 60, SuperNeutral 68, AGC Comfort Ti-AC 40
	<u>Single silver</u> Viracon VE1-85, Cardinal LoE-179, PPG Sungate 100, Guardian 75/68
	<u>Pyrolytic</u> PPG Sungate 500, Pilkington Energy Advantage, AGC Comfort E2
Substrates	<u>Green</u> PPG Solexia, AGC Solarshield Green
	<u>Dark green</u> Solarshield Dark Green
	<u>Blue-green</u> Pilkington Optifloat Blue-Green
	<u>Bronze</u> Pilkington Optifloat Bronze
	<u>High-performance</u> PPG Azuria, Pilkington EverGreen
Frames	<u>Thermal break</u> Fixed: Kawneer 8225TL, NX-3800, EFCO 2700, Peerless G341, YKK YCW 750 XT Casement/Awning: EFCO 2900 Curtainwall/Storefront: EFCO 5600 Slider: EFCO 3500 Glazed Door: TRACO 8910, EFCO 3015
Spacers	<u>Mild steel</u> Hygrade HY-NZ Steel, Allmetal HiQ Steel (or CMAST Path 1, Group 2)
	<u>Hybrid steel</u> PPG Intercept TPU

Code Simplification

The following is a quote from the research report supporting the California 2013 Standards

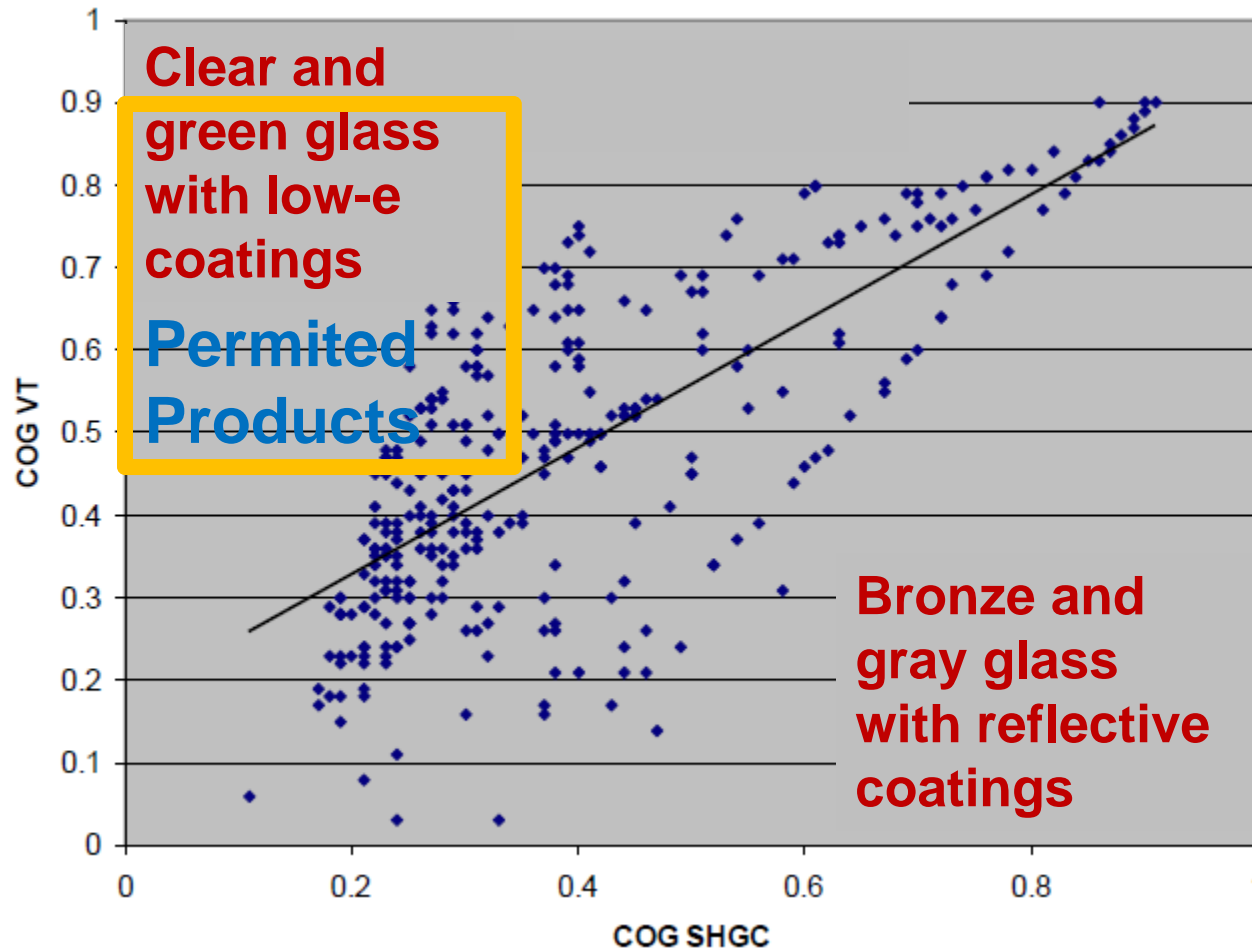
***“ . . . there is a move towards simplification of the Standards. . . .
This code simplification included:***

- ***A single SHGC and VT for all fenestration ratios up to the maximum fenestration ratio***
- ***A single U-factor, SHGC and VT for all climate zones***
- ***A single SHGC and VT for all orientations***

Source: Nonresidential & High-Rise Residential Fenestration Requirements, 2013
California Building Energy Efficiency Standards, California Utilities Statewide Codes and
Standards Team September 2011

Progression of Prescriptive Requirements

Visible Light Transmission



Now a prescriptive requirement in California

Source: Nonresidential & High-Rise Residential Fenestration Requirements, 2013
California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team September 2011

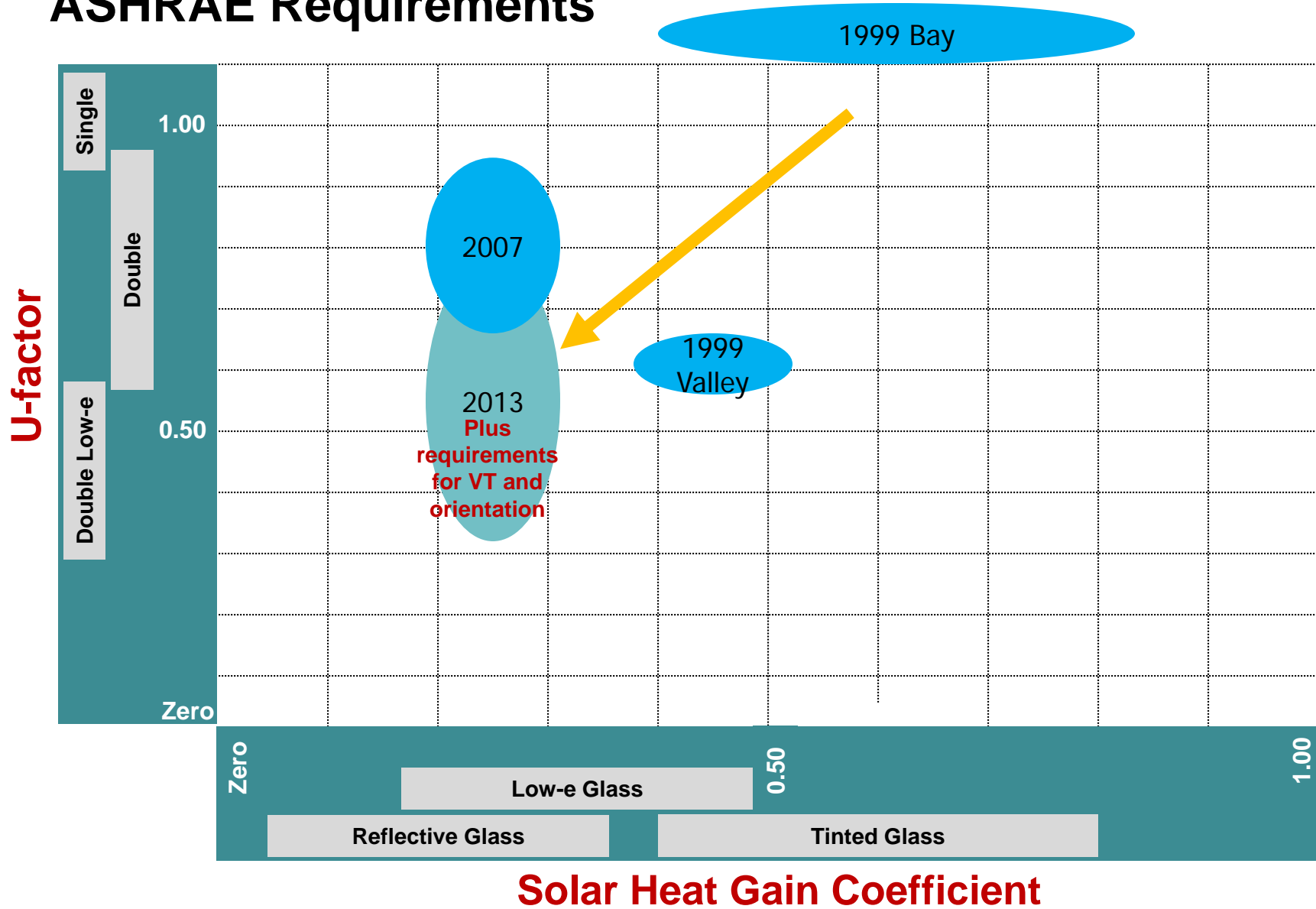
Progression of Prescriptive Requirements

ASHRAE Requirements

	Climate	U-factor	SHGC			VT
ASHRAE 1999	Bay (B12)	1.22 Fixed	WWR	All	North	No requirement
		1.27 Operable	10%	0.61	0.82	
			20%	0.61	0.82	
			30%	0.61	0.61	
	Valley (B11)	0.57 Fixed 0.67 Operable	WWR	All	North	
			10%	0.39	0.49	
			20%	0.39	0.49	
			30%	0.39	0.49	
ASHRAE 2004	3C Bay and Valley	0.57 Fixed	WWR	All	North	No requirement
		0.67 Operable	10%	0.39	0.49	
			20%	0.25	0.49	
			30%	0.25	0.39	
			40%	0.25	0.39	
ASHRAE 2007 and 2010	3C	0.65 Nonmetal	0.25 All			No requirement
		0.60 Curtainwall				
		0.90 Entrance door				
		0.95 Metal (other)				
ASHRAE 2013	3C	0.35 Nonmetal	0.25 All			VT/SHGC \geq 1.10
		0.50 Metal Fixed				
		0.60 Metal Operable				
		0.77 Entrance door				

Progression of Prescriptive Requirements

ASHRAE Requirements



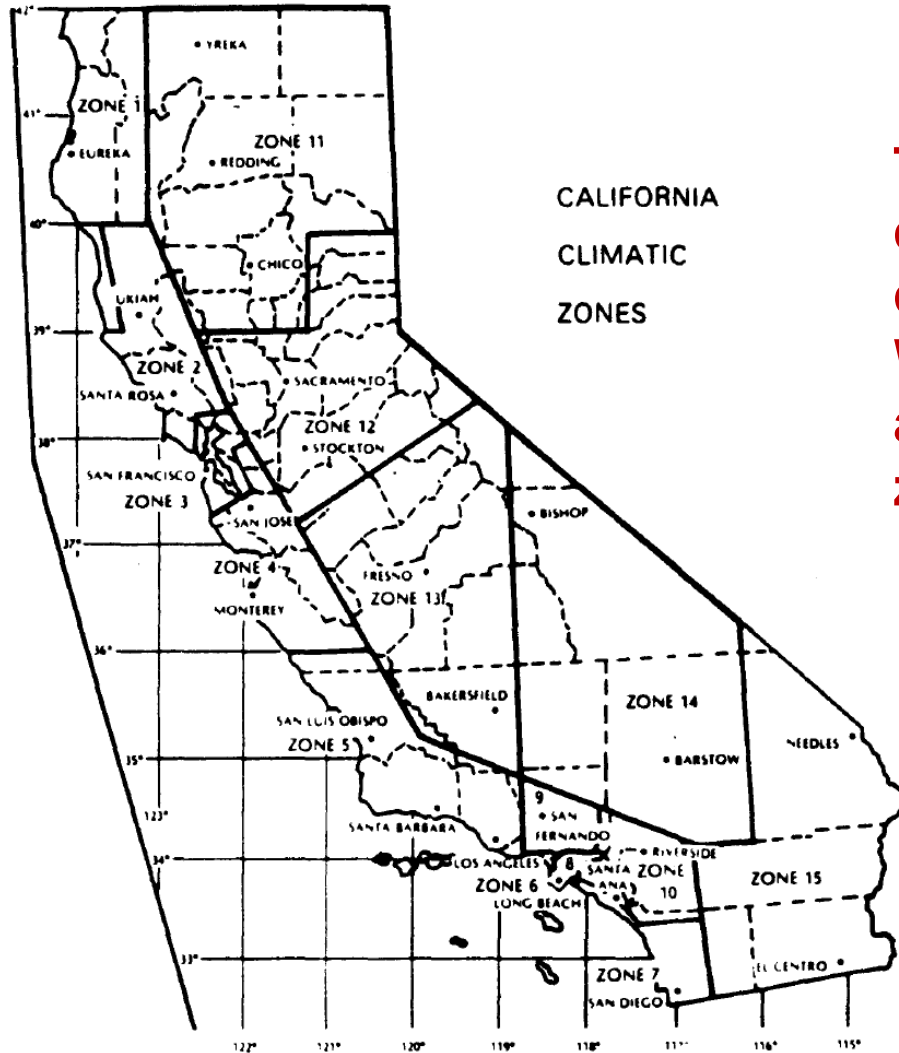
Performance Standards

First Generation Energy Budgets

Table 2-1
 Maximum Allowable Energy Consumption Per Year
 (Thousands of British Thermal Units Per Gross Square Foot of Conditioned Floor Area)

UBC Occupancy (1)	Occupant Load (2)	Climatic Thermal Zones 1-5 (3)			Climatic Thermal Zones 6,8,9,10			Climatic Thermal Zone 7			Climatic Thermal Zones 11, 12, 13			Climatic Thermal Zones 14,15		
		Heated & Cooled (4)	Heated Only	Cooled Only	Heated & Cooled	Heated Only	Cooled Only	Heated & Cooled	Heated Only	Cooled Only	Heated & Cooled	Heated Only	Cooled Only	Heated & Cooled	Heated Only	Cooled Only
A	drinking and dining establishments	131	126	82	108	102	82	104	103	80	132	119	96	148	109	126
	all others	159	154	64	123	114	68	118	106	71	155	140	86	189	120	141
B-1		180	171	163	191	163	184	189	162	184	196	173	185	243	168	236
B-2	offices under 300	141	135	134	145	133	142	145	132	143	148	139	140	165	137	160
	offices over 299	126	125	124	129	128	128	131	130	131	134	131	130	132	129	128
	retail grocery stores	214	212	167	194	189	176	192	187	176	235	216	199	255	204	229
	other retail stores under 300	180	171	163	191	163	184	189	162	184	196	173	185	243	168	236
	other retail stores over 299	200	195	190	207	195	202	209	196	204	213	199	205	231	205	225
	drinking and dining establishments	131	126	82	108	102	82	104	103	80	132	119	96	148	109	126
class-rooms		120	118	77	105	94	82	101	94	83	156	143	89	141		

First Generation California Climate Zones

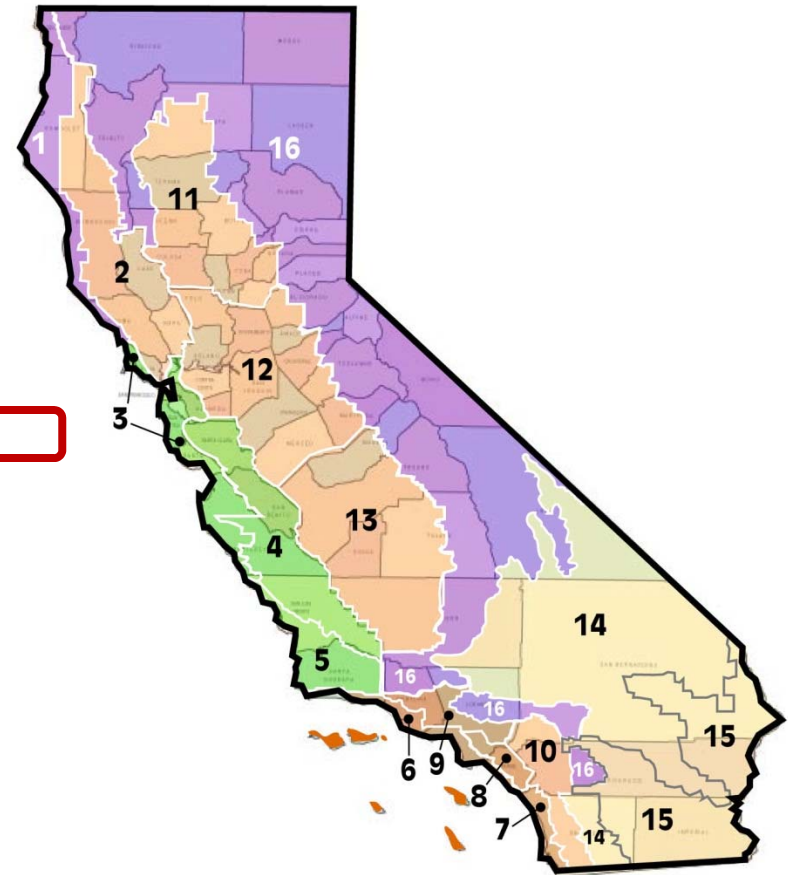


There is some differentiation along the coast, but note that Walnut Creek and Truckee are in the same climate zone

2nd Generation Energy Budgets for Offices

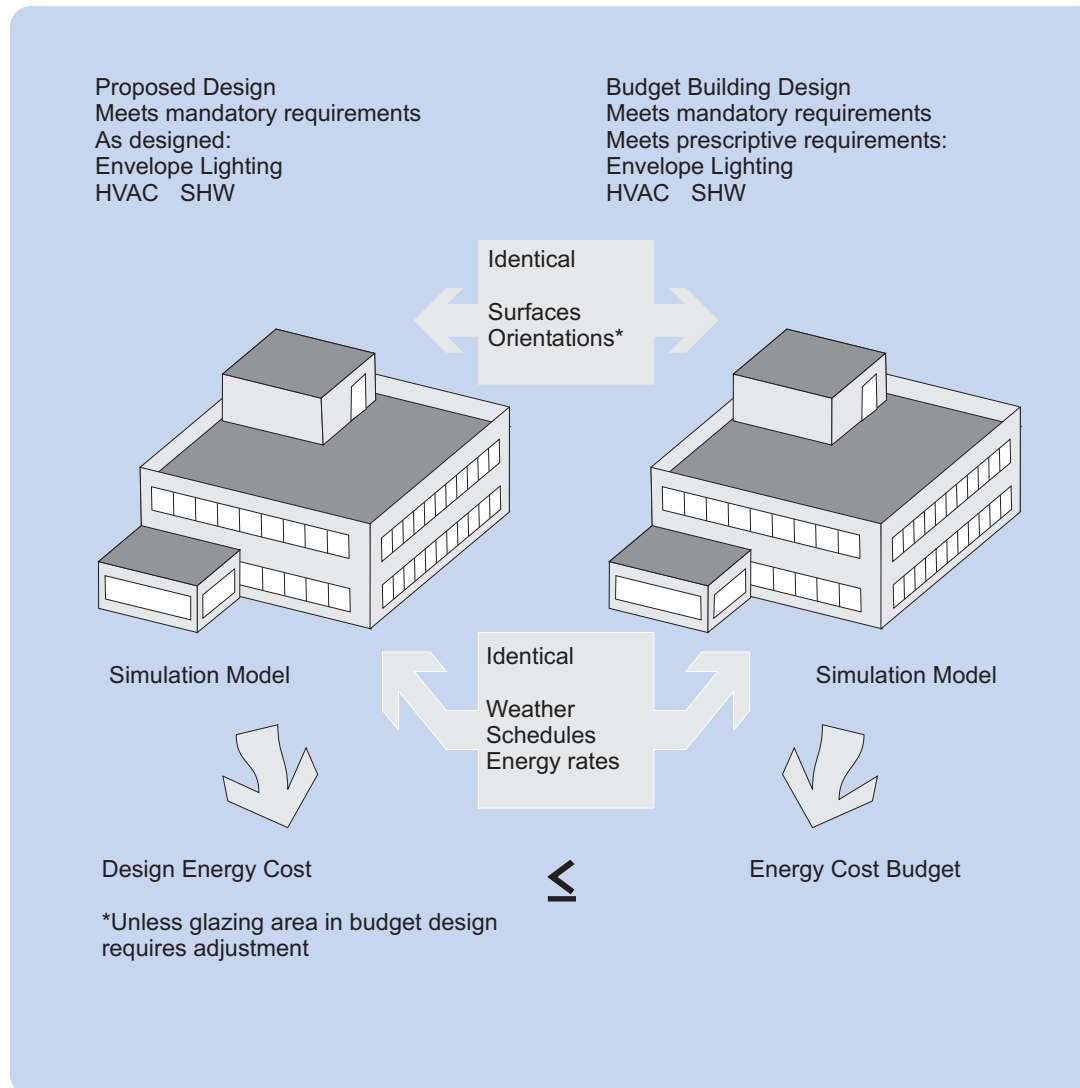
TABLE 2-53R
ENERGY BUDGETS FOR OFFICES IN BUILDINGS OF THREE OR FEWER HABITABLE STORIES
[kBtu per square foot of conditioned floor area per year]

Climate Zone	Conditioned Area-to-Conditioned Perimeter Ratio ^{1,2}							
	13.74 or less	13.75 to 15.99	16.00 to 19.99	20.00 to 22.49	22.50 to 24.99	25.00 to 27.49	27.50 to 29.99	30.00 or more
1	139	131	124	113	106	101	97	92
2	184	172	162	146	135	127	121	114
3	133	125	119	109	103	98	94	90
4	142	135	128	117	109	103	100	95
5	141	133	126	115	107	102	98	93
6	198	183	170	151	137	127	119	110
7	146	138	131	120	112	107	103	98
8	158	148	140	127	118	112	108	102
9	170	160	151	137	126	119	113	107
10	189	177	166	149	138	130	124	117
11	222	207	194	174	159	148	140	130
12	205	189	176	156	143	133	127	119
13	210	196	184	166	152	142	135	126
14	233	217	203	182	166	155	146	136
15	261	244	229	205	188	175	166	154
16	194	181	170	153	140	131	125	117



¹ The conditioned area-to-conditioned perimeter ratio may be applied for each story of a building or each tenant space in any single story of a building.
² The budgets for a multi-story building may be met on a total building basis under Section 2-5304(d)2.

The Custom Budget Approach



1988 – First implemented in California

1999 – Included in ASHRAE 90.1

2004 – ASHRAE added the PRM in Appendix G

- Baseline is rotated
- WWR is fixed with latest version

California comparison was based on source energy but was changed to TDV energy in 2005

Tradeoffs with California 2013

Proposed Design

- Fenestration modeled with PD U-factor, SHGC and VT
- Penalty if
 - U, SHGC is higher
 - VT is lower
 - No daylighting controls

Baseline Building

- Fenestration has the prescriptive U-factor, SHGC and VT levels
- Automatic daylighting controls
 - In primary daylighting zone
 - Under skylights

WWRs in ASHRAE Performance Rating Method

TABLE G3.1.1-4 Baseline Building Vertical Fenestration Percentage of Gross Above-Grade-Wall Area

Building Area Types ^a	Baseline Building Gross Above-Grade-Wall Area
Grocery Store	7%
Healthcare (outpatient)	21%
Hospital	27%
Hotel/motel (≤ 75 rooms)	24%
Hotel/motel (> 75 rooms)	34%
Office (≤ 5000 ft ²)	19%
Office (5000 to 50,000 ft ²)	31%
Office ($> 50,000$ ft ²)	40%
Restaurant (quick service)	34%
Restaurant (full service)	24%
Retail (stand alone)	11%
Retail (strip mall)	20%
School (primary)	22%
School (secondary and university)	22%
Warehouse (nonrefrigerated)	6%

a. In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Comparison of Performance Methods

	California and ASHRAE ECB	Performance Rating Method
Window Area	Neutral if less than 40%	Asset
Window Orientation	Neutral	Asset
U-factor	Asset	Asset
SHGC	Asset	Asset
VT	Asset	Asset

CBECC-Com

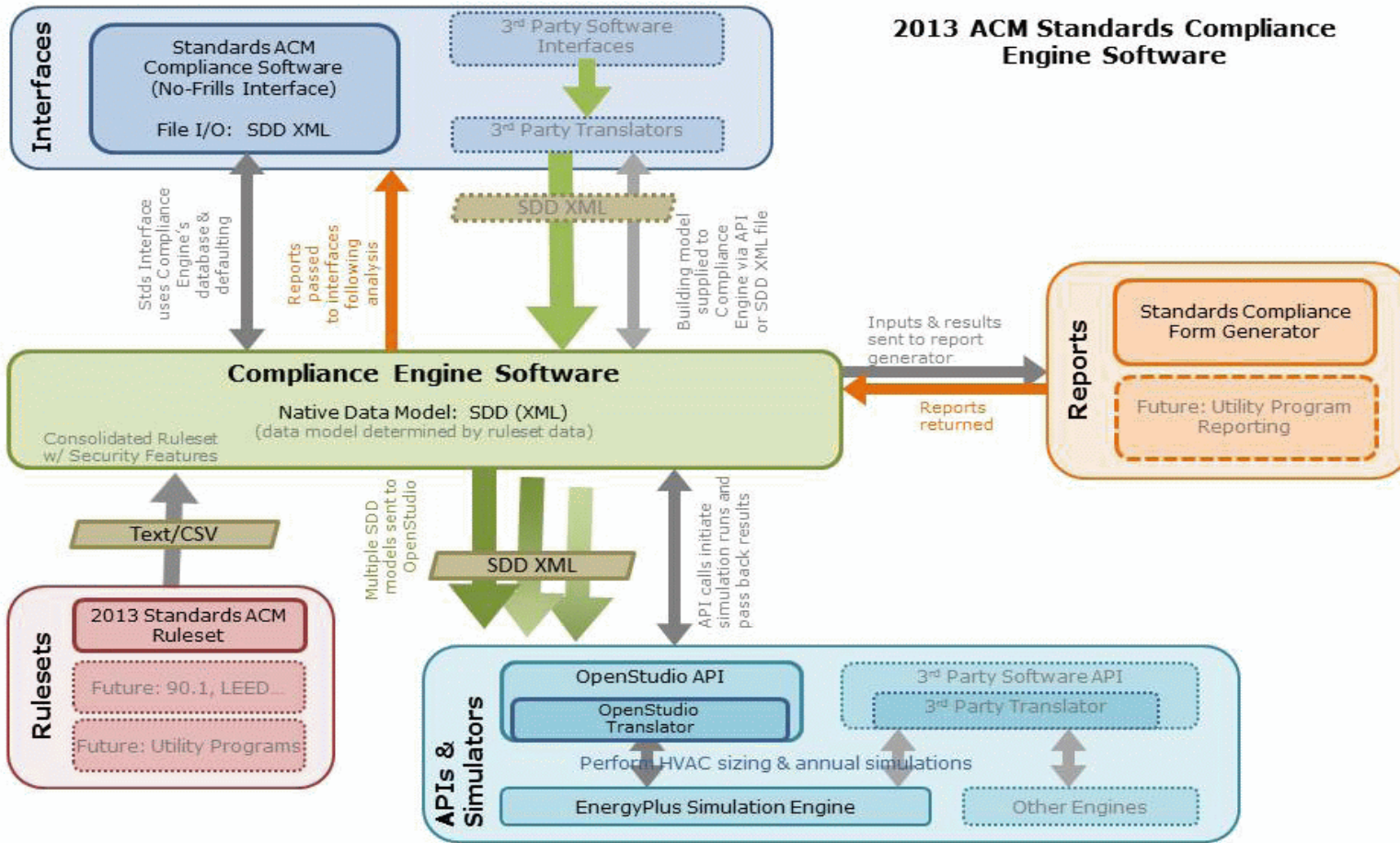


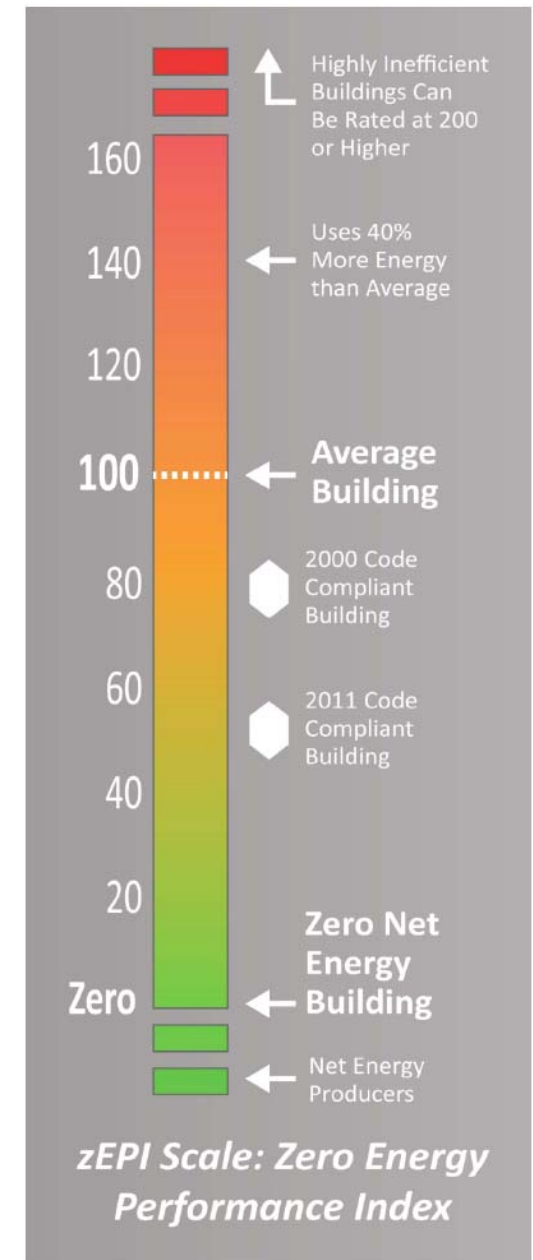
Diagram key:

- Transfer of building model via SDD (XML) (multiple arrows imply transfer of multiple building models)
- Transfer of compliance reports
- Inter-process communication of data and/or API calls
- Pale Blocks Possible future modules

Zero Energy Performance Index


Zero Energy Performance Index

- A stable scale that does not change over time
- Same scale for code compliance, LEED energy points, utility incentive programs and green building ratings
- Baseline does not change so that software developers have more incentive to automate the process.



Movement Towards zEPI

- IgCC
- 90.1-2013 Addendum BM (proposed)
- ASHRAE Building EQ Rating System
- ASHRAE Standard 189.1
 - Referenced by CalGreen
 - Referenced by IgCC
 - MOU with ICC



BSR/ASHRAE/IES Addendum bm
to ANSI/ASHRAE/IES Standard 90.1-2013

Public Review Draft

**Proposed Addendum bm to
Standard 90.1-2013, Energy Standard
for Buildings Except Low-Rise
Residential Buildings**

Third Public Review (August 2014)
(Draft shows Proposed Changes to Previous Public Review Drafts)

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zEPI Resources (available at eley.com/resources)

Codes & Standards Development

Rethinking Percent Savings


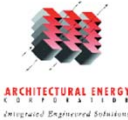
The Problem with Percent Savings and the New Scale for a Zero Net-Energy Future



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July 22, 2009



ARCHITECTURAL ENERGY
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Integrated Engineering Solutions

Go to www.newbuildings.org and click on: Rethinking Percent Savings

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Rethinking Percent Savings— The Problem with Percent Savings and zEPI: The New Scale for a Net Zero Energy Future

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ABSTRACT

This paper proposes a stable metric for comparing the energy efficiency of buildings. The paper examines the problem of using "percent savings better than a given energy code" to appraise a building's energy performance. The baseline for this metric, "a given energy code," can vary greatly in its inherent efficiency. As an alternative, the paper recommends a new scale—the Zero Energy Performance Index (zEPI)—that can be used to evaluate buildings in a stable, elegant manner. A zEPI score of "0" would be a net zero energy building, while a score of "100" represents a building with average energy consumption as of the year 2000. The score for a given building will be higher or lower in linear relationship to the year 2000 benchmark. Finally, the benefits of zEPI are examined, including those for energy codes, building rating programs, incentive programs, and addressing non-regulated energy loads.

INTRODUCTION

Energy incentive programs, green building rating systems, and energy labeling programs are commonly based on percent savings past code minimum. This approach has worked reasonably well, but percent savings becomes confusing and unstable as policy makers set goals for net zero energy buildings and as energy codes become more stringent.

Percent savings is confusing because the codes frequently change. California updated its energy efficiency standards in 2001, 2005, and 2008; each time, energy use was reduced from between 5% and 8% (CEC 2001, 2006, 2008a). ASHRAE updated Standard 90.1 in 1999, 2001, 2004, and 2007 (ASHRAE 1999, 2004, 2007a). Early green buildings claimed savings of 40% or more relative to ASHRAE Standard 90.1-1999, but many of these buildings would fail to comply with the most recent ASHRAE and California codes.

Percent savings is also confusing because, in many cases, not all of the energy used in buildings is considered. With LEED 2.1 and other early programs, only regulated energy was considered, such as heating, cooling, ventilation, hot water, and interior lighting (USGBC 2002). Process energy, plug loads, commercial refrigeration, and other non-regulated energy uses were not included because the codes did not establish a baseline for these end uses. In some building types, like supermarkets and restaurants, the non-regulated energy can represent two thirds of the total. Even in offices and schools, non-regulated energy typically represents about one third of total energy. Ignoring non-regulated energy in the percent savings calculations overstates the percent savings and provides a false perception to building owners as to what the energy savings benefits will be.

This paper proposes a more stable scale to replace percent savings: the Zero Energy Performance Index (zEPI). This scale can be used as the basis for incentive programs, green building rating systems, and energy labels. Updates to energy codes can be evaluated using zEPI, as opposed to having code updates redefine the scale. zEPI will work for all building types from offices and schools to energy-intensive building types such as supermarkets and laboratories.

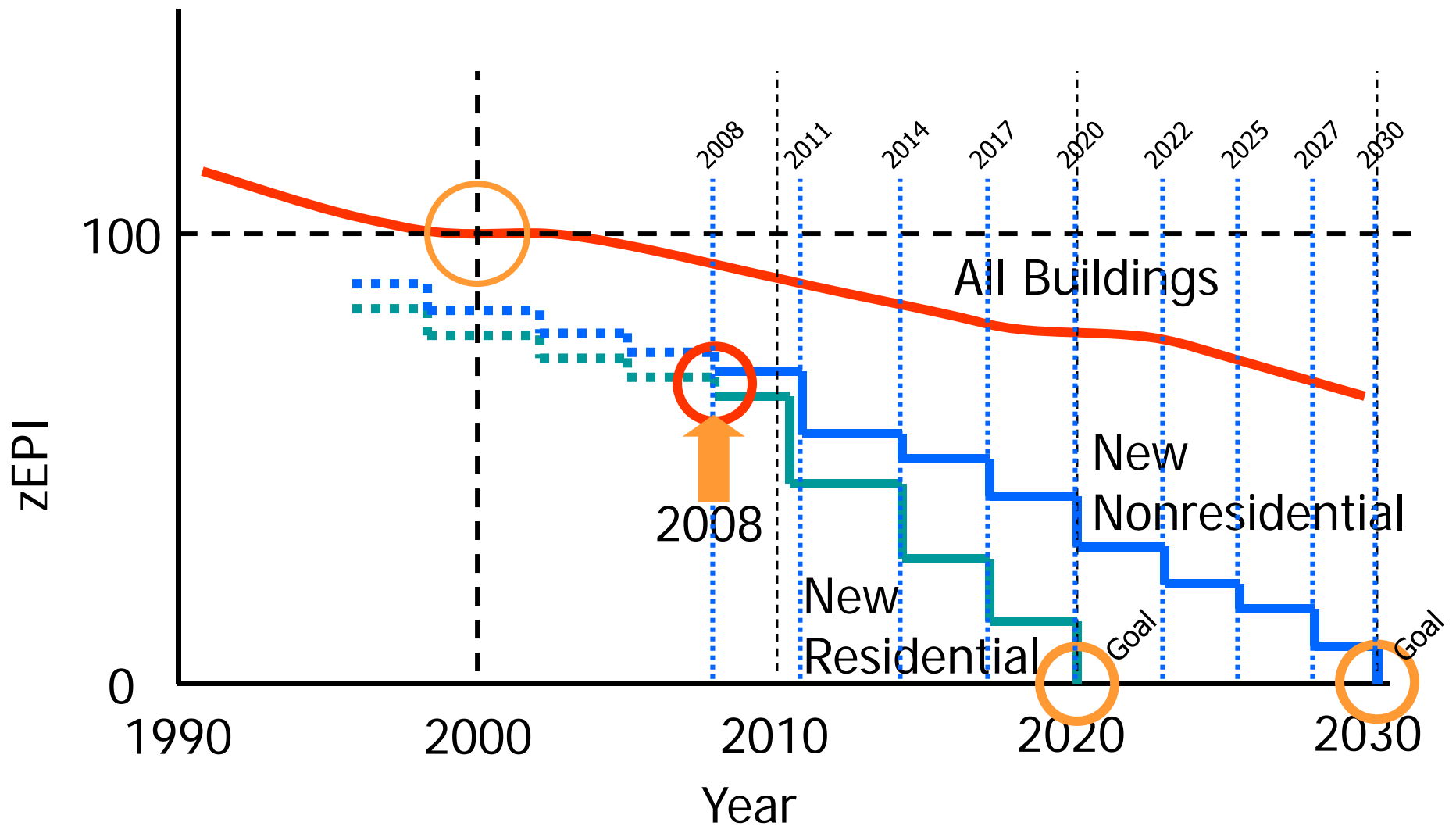
Net zero energy is a pure goal, needing no point of comparison. As used here, it means that for a typical year, a building will produce as much energy as it uses. The "net" part means that the building is using the utility grid as its "battery," charging the battery when the building is producing more energy than it is using and drawing from the battery during the night and at other times when it is consuming more energy.

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More technical piece published in the ASHRAE 2011 summer proceedings

Using the zEPI as a Framework for Code Development



Questions and Clarifications

