

2009 International Energy Conservation Code (IECC) & Design Strategies to Achieve Compliance

Honolulu, Nov. 13 & 14, 2012

Lihue, Nov. 15, 2012

Kahului, Nov. 16, 2012

Hilo, Nov. 19, 2012

Kona, Nov. 20, 2012

**Afternoon
Session**

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Task Order Number 2.F

Agenda

Afternoon Session

INTRODUCTION

1:00	Introduction
1:15	Design strategies for AC residence
2:30	BREAK
2:45	Design strategies for small commercial project
3:45	Wrap up
4:00	Adjourn

Learning Objectives

- Identify appropriate roof construction alternatives, especially those with cool roofs and radiant barriers
- Identify appropriate construction alternatives for wood-framed, steel-framed and masonry walls
- Select a complying window, in combination with shading alternatives
- Select complying lighting fixtures
- Identify efficient air-conditioning compliance alternatives

The background of the slide is a photograph of a large, mature tree with a thick trunk and dense foliage. The entire image is overlaid with a semi-transparent green filter. The text is positioned in the lower-left quadrant of the slide.

2009 IECC

DESIGN PROCESS

Designing for Compliance Steps

- Check scope of code
- Review checklist
- Identify compliance paths
 - prescriptive
 - performance
- Identify compliance options
 - Roof
 - Walls
 - Windows/shading



2009 IECC

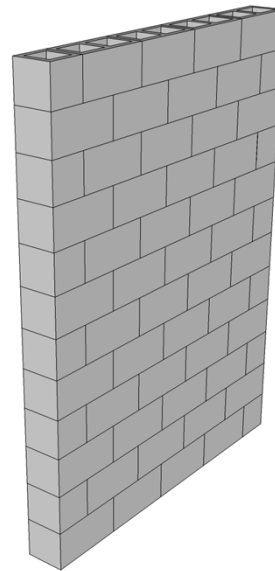
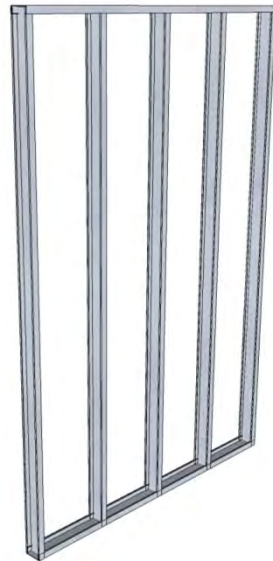
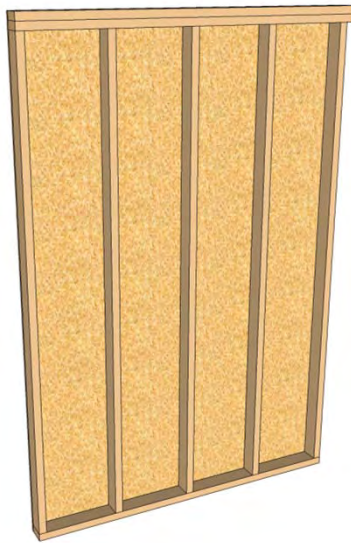
AC RESIDENCE ENVELOPE STRATEGIES

- No floor insulation requirements!
 - Slab-on-grade
 - Raised floor
 - Basement walls
 - Crawlspace walls

Walls

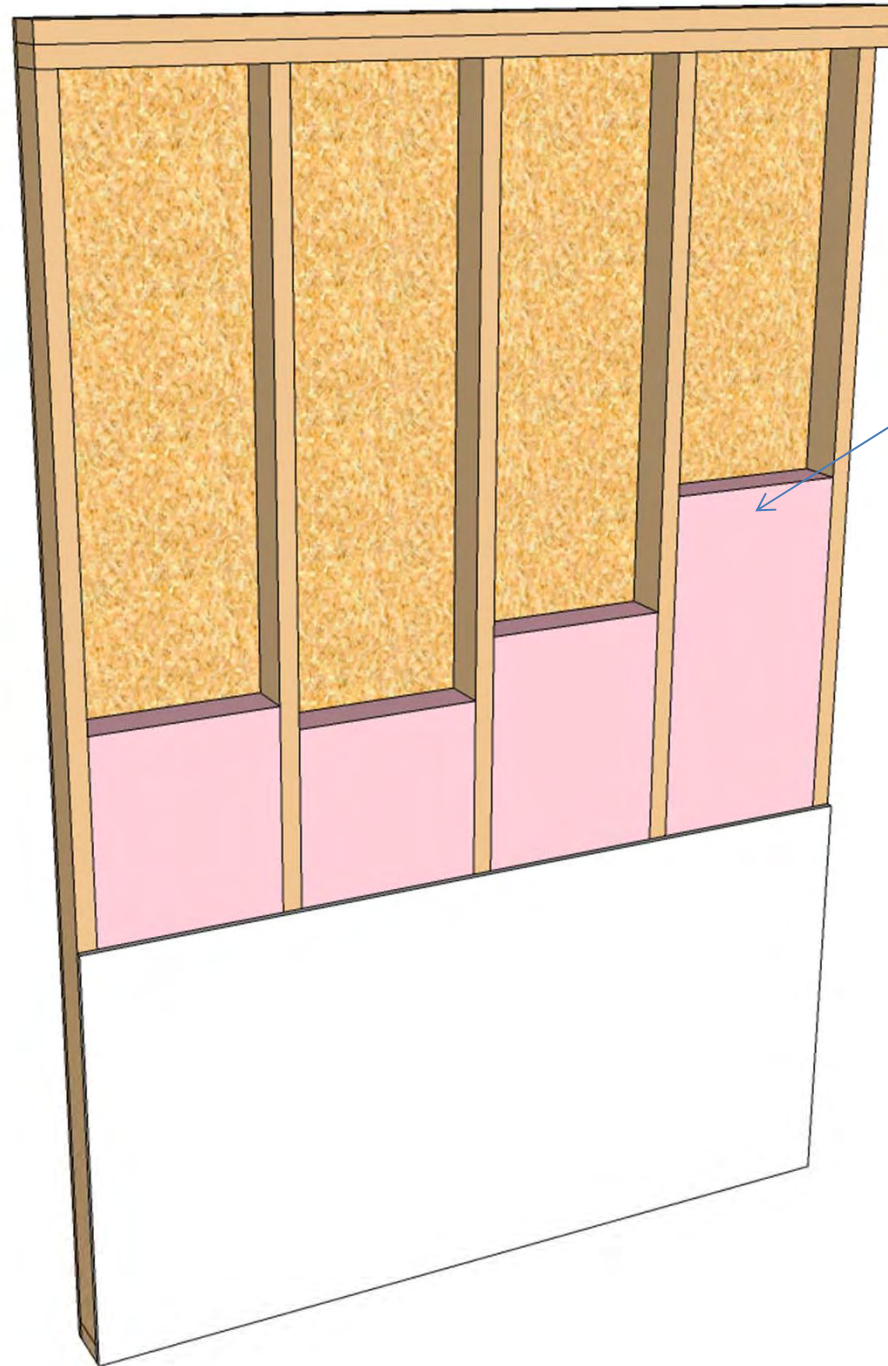
RESIDENTIAL
Envelope

- Wood frame
- Steel frame
- Mass wall – concrete masonry unit (CMU)
- Structural insulated panel (SIP)



WOOD FRAME WALL

R-value
compliance
option
(402.1.1)



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R-13 insulation

Typical options:

- Fiberglass batt
- Blown cellulose
- Spray foam

3 ½ in. typical thickness

For spray/blown
insulation, installer
posts R-value
certification at job site
(303.1.1)

Spray foam insulation example

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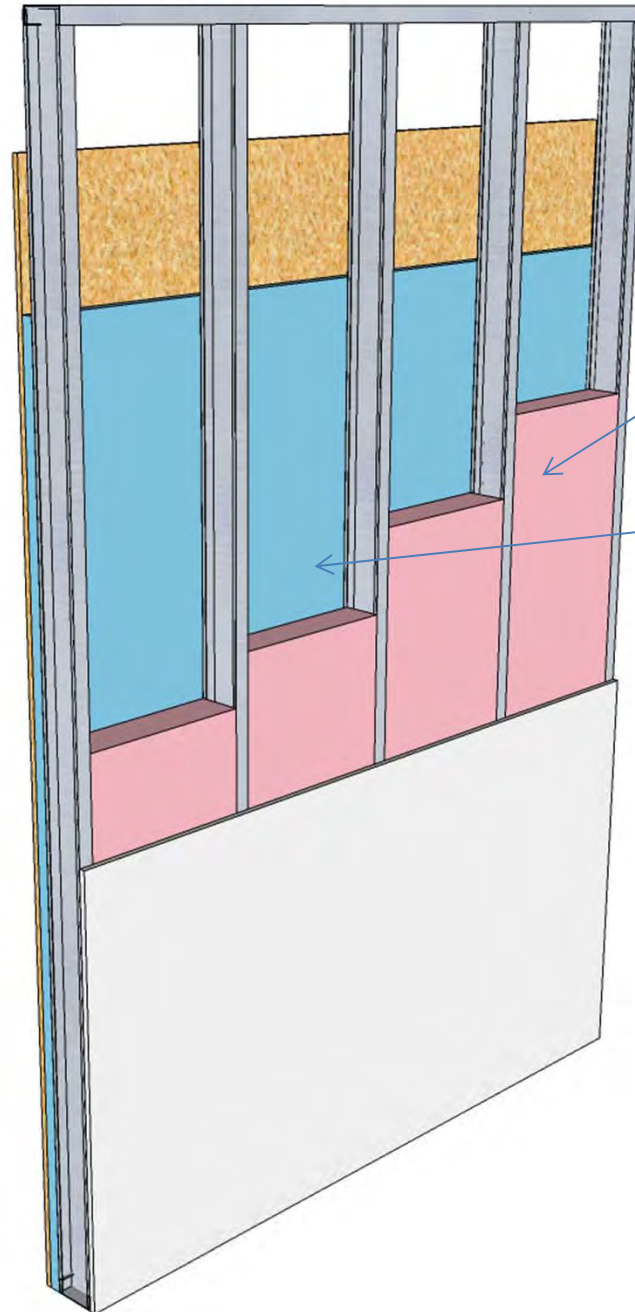
Source: DOE/NREL PIX13528



Source: DOE/NREL PIX11530

STEEL FRAME WALL

R-value
compliance
option
(402.2.5)



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R-13 insulation

+ R-5 continuous
insulation

Typical R-5 options:

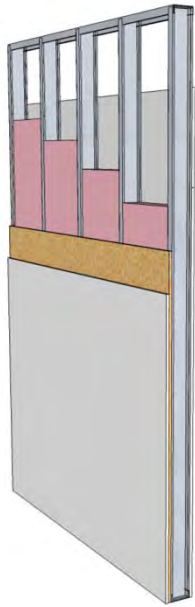
- 1 in. extruded polystyrene foam
- ¾ in. polyisocyanurate foam

STEEL FRAME WALL

Hawaii Exceptions
(Amendment to 402.2.5)

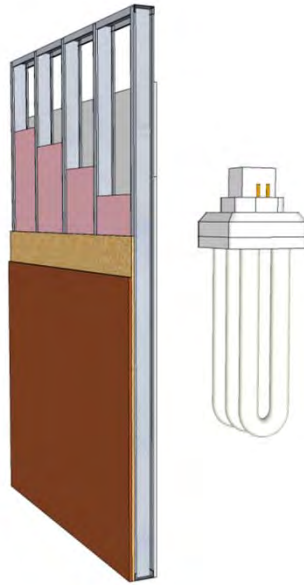


R-13 insulation alone
(no R-5 required)
if design meets one of
the following...



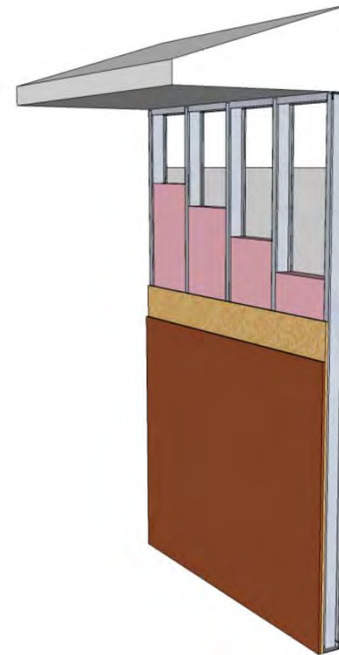
1.

Reflectance ≥ 0.64



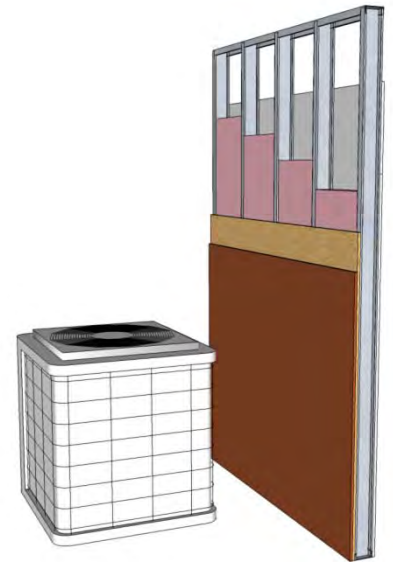
2.

$\geq 90\%$
high efficacy
lamps



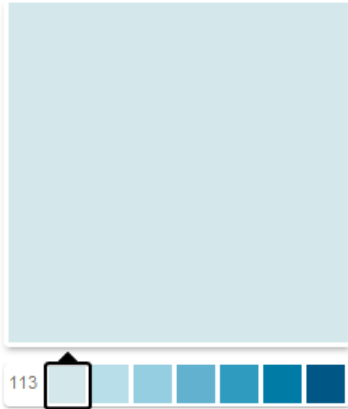
3.

Overhang
projection factor
 ≥ 0.3 on
non-north



4.

14+ SEER air
conditioner



SW 6784 Bravo Blue

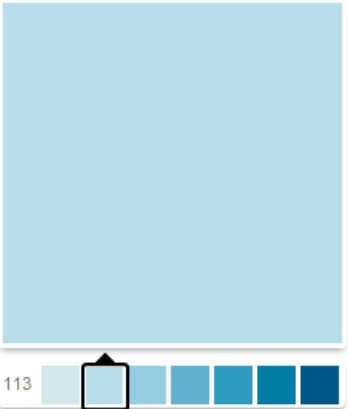
Interior/Exterior

Color Collection SW Color
Color Family Blues
Color Strip 113
RGB Value R-212 | G-231 | B-234
Hexadecimal Value #D4E7EA

LRV 78

Example
Light Reflectance Value (LRV) for exemption $\geq 64\%$

OK, LRV 78



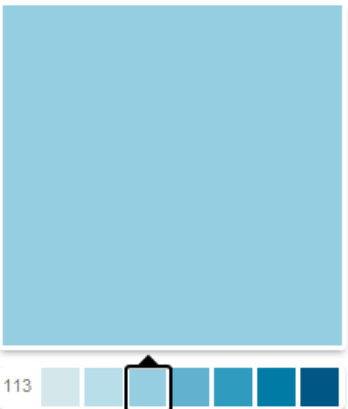
SW 6785 Quench Blue

Interior/Exterior

Color Collection SW Color
Color Family Blues
Color Strip 113
RGB Value R-184 | G-222 | B-233
Hexadecimal Value #B8DEE9

LRV 69

OK, LRV 69



SW 6786 Cloudless

Interior/Exterior

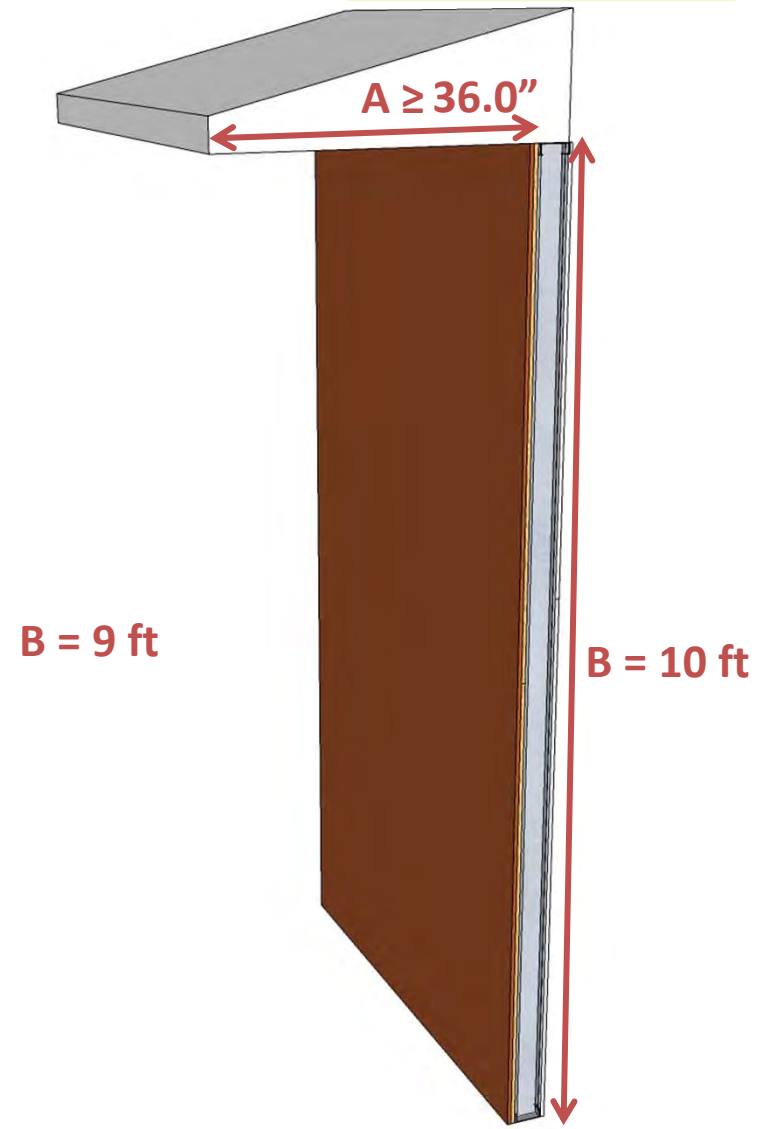
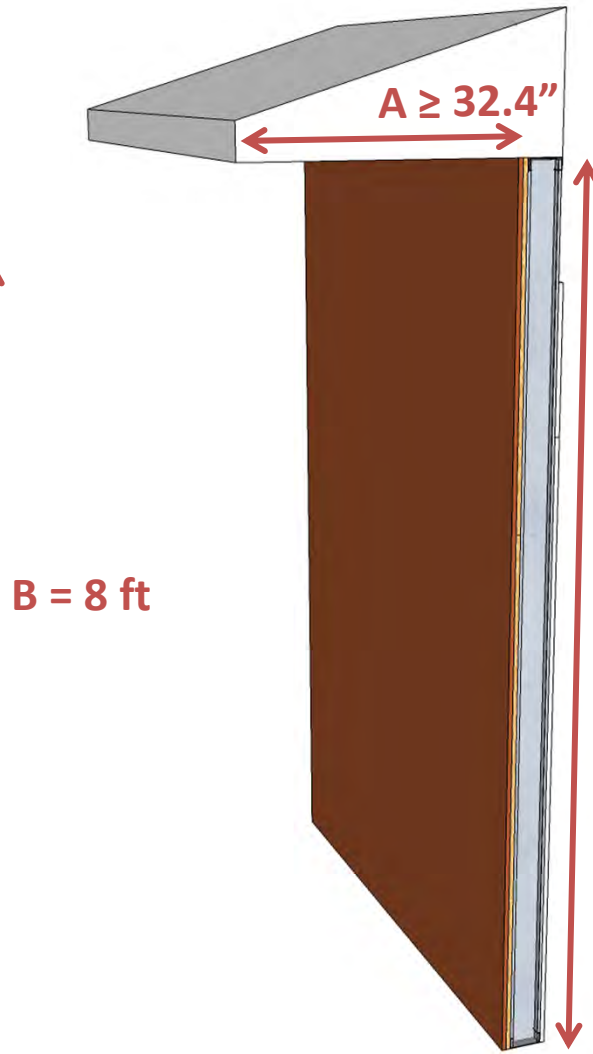
Color Collections SW Color , Teen Space
Color Family Blues
Color Strip 113
RGB Value R-149 | G-206 | B-224
Hexadecimal Value #95CEE0

LRV 57

Not complying, LRV 57

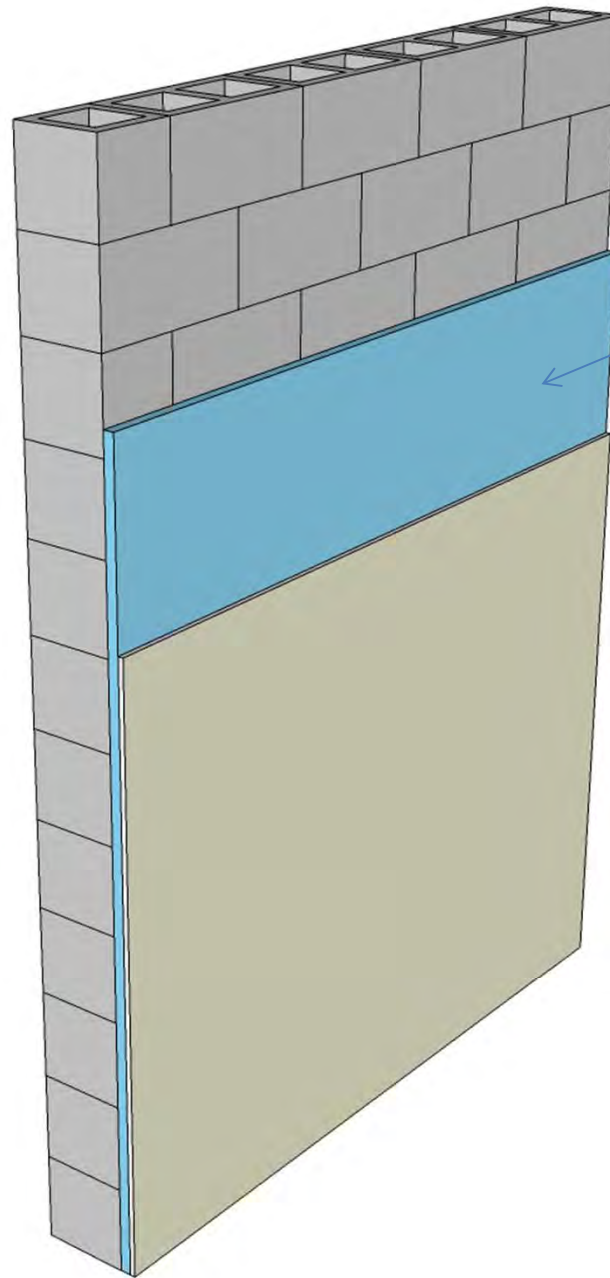
QUALIFYING WALL OVERHANGS

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MASS WALL

R-value
compliance
option
(402.1.1)



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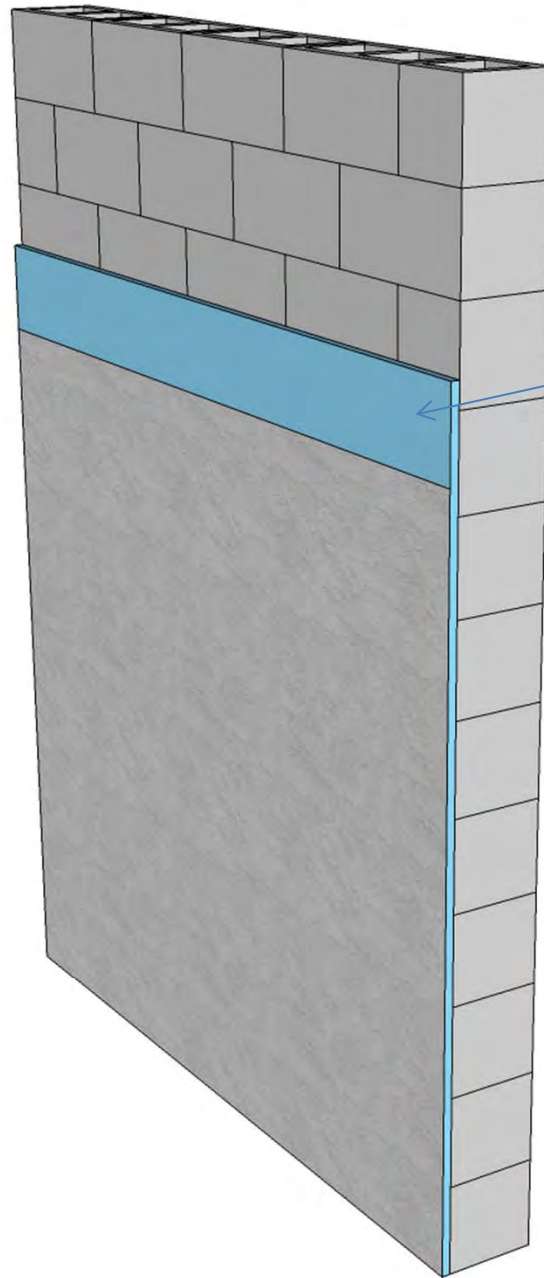
R-4 insulation
on interior side

Typical R-4 options:

- $\frac{3}{4}$ to 1 in. extruded polystyrene foam
- $\frac{1}{2}$ to $\frac{3}{4}$ in. polyisocyanurate foam

MASS WALL

R-value
compliance
option
(402.1.1)



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R-3 insulation
on exterior side

Typical R-3 options:

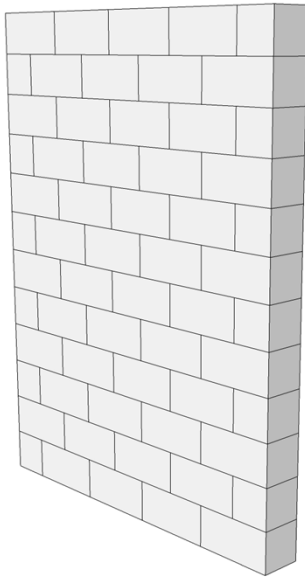
- ¾ in. extruded polystyrene foam
- ½ in. polyisocyanurate foam

MASS WALL

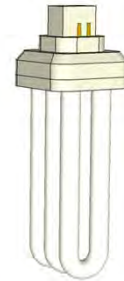
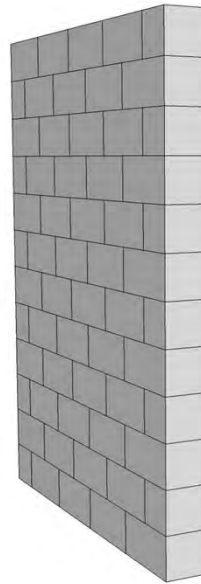
Hawaii Exceptions
(Amendment to
Table 402.1.1)



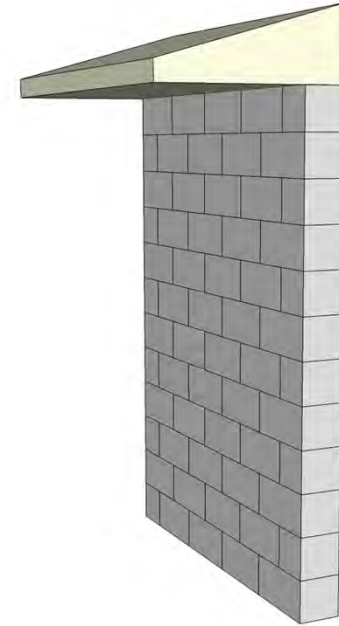
No insulation required if
design meets one of the
following



1.
Reflectance ≥ 0.64



2.
 $\geq 90\%$
high efficacy
lamps



3.
Overhang
projection factor
 ≥ 0.3 on
non-north

Structural Insulated Panel (SIP) Wall

U-factor compliance option (402.1.3)



0.082 Btu/hr-sf-F maximum



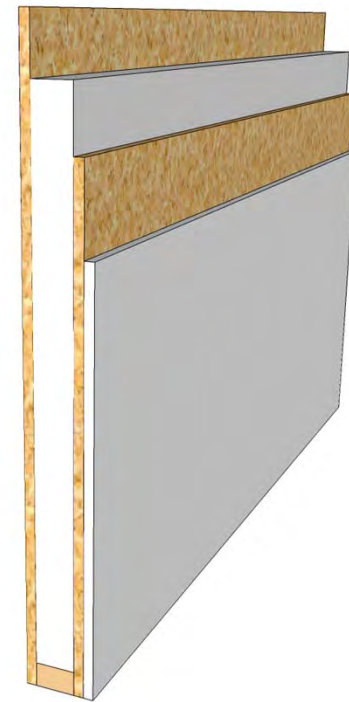
Layer	R-value
Outdoor air film	0.17
Exterior OSB, ½ in.	0.62
Insulation	9.7
Interior OSB, ½ in.	0.62
Gypsum board, ½ in.	0.45
Indoor air film	0.68
TOTAL R-VALUE	12.2
U-factor (=1/R-value)	0.082



Minimum Insulation Thickness

- 2½ in. expanded polystyrene
- 2 in. extruded polystyrene
- 1¾ in. polyisocyanurate

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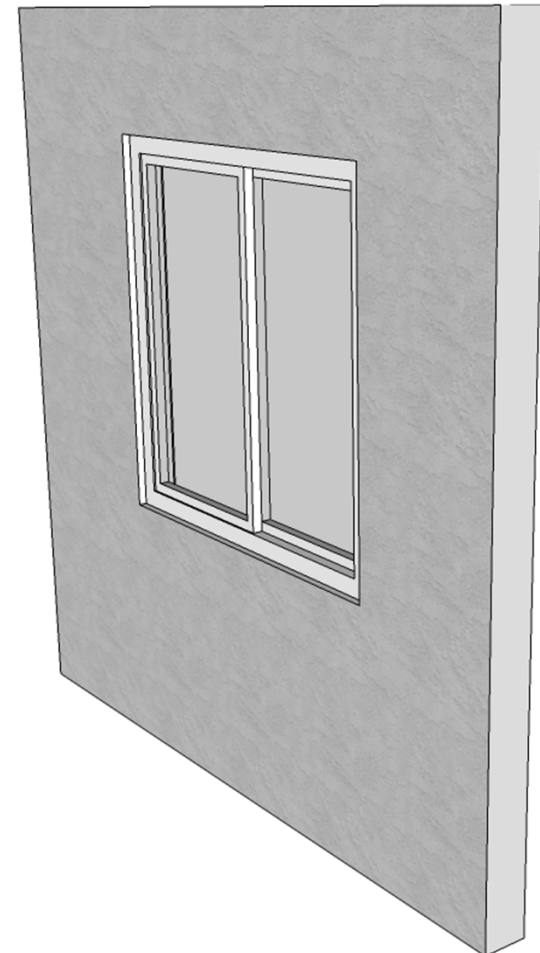
Structural Insulated Panel (SIP)

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Source: DOE/NREL PIX02107

- Compliance options
 1. Glazing alone
 - $SHGC \leq 0.30$ on east, south, west
 - North-facing exempt
 2. Overhang shading alone
 - Projection factor ≥ 1.0
 3. Combinations
 - Hawaii window spreadsheet



WINDOWS

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Sample complying residential window products

Dual-pane, low-e, solar control

SHGC ≤ 0.30

Low-E Products	Visible Light			UV Trans	UV Tdw-ISO	SHGC	U-Factor	
	Trans	Reflect Out	Reflect In				Argon	Air
ClimaGuard 55/27	55%	12%	17%	18%	41%	0.275	0.243	0.290
AGC Comfort Ti-AC 23™	40%	12%	11%	19%	35%	0.220	0.249	0.296
Cardinal LōE - 240™	40%	14%	10%	16%	35%	0.251	0.256	0.302
Cardinal LōE - 366™	65%	11%	12%	5%	43%	0.272	0.242	0.289
PPG Solarban® 70 XL	64%	12%	13%	6%	43%	0.271	0.240	0.288

*Double glazed: 3.0mm Clr, 1/2" Gap, 3.0mm Clr: Air and 90% Argon/10% Air Filled Units
Low-E coatings on the #2 surface*

Source: www.guardian.com

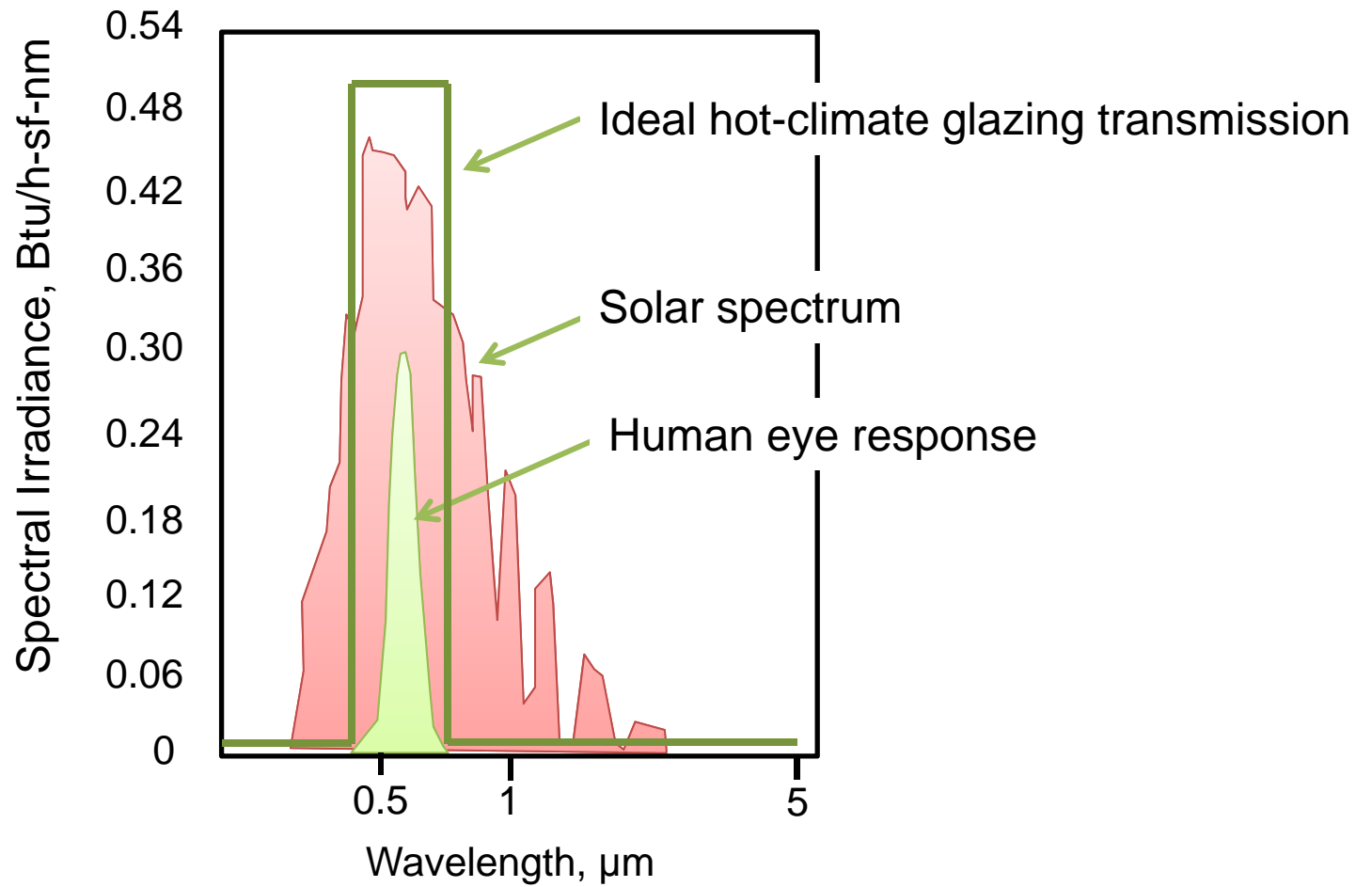


Low UV transmission
is an extra benefit

WINDOWS

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Spectrally
selective
glazing



WINDOWS

NFRC Label
(National Fenestration Rating Council)

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	<p>World's Best Window Co.</p> <p>Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Argon Fill • Low E Product Type: Vertical Slider</p>	
<p>ENERGY PERFORMANCE RATINGS</p>		
<p>U-Factor (U.S./I-P)</p> <p>0.30</p>	<p>Solar Heat Gain Coefficient</p> <p>0.30</p>	
<p>ADDITIONAL PERFORMANCE RATINGS</p>		
<p>Visible Transmittance</p> <p>0.51</p>	<p>Air Leakage (U.S./I-P)</p> <p>0.2</p>	
<p>Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information. www.nfrc.org</p>		

Source: www.nfrc.org

WINDOWS

NFRC Website Product Directory



Directory Search

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Back New Search

Required Criteria for Window

*Window Manufacturers(718):

*Available Window types(8): [If you would like examples of Window types please click here](#)

Performance Criteria (Optional)

U-Factor ($0 \leq x < 2$): SHGC ($0 \leq x < 1$): VT ($0 \leq x < 1$):
Min: Max: Min: Max: Min: Max:

Product Criteria (Optional)

Frame Type: <input type="text" value="Vinyl"/> <input type="button" value="v"/>	Sash Type: <input type="text" value="Select Sash"/> <input type="button" value="v"/>	Glazing Layers: <input type="text" value="Select # of Glazing Layers"/> <input type="button" value="v"/>
Low-E Range: <input type="text" value="Low Solar Heat Gain"/> <input type="button" value="v"/>	Low-E Surface: <input type="text" value=""/> <input type="button" value="v"/>	Grid: <input type="text" value="Select Grid"/> <input type="button" value="v"/>
Dividers: <input type="text" value="Select Divider"/> <input type="button" value="v"/>	Spacer: <input type="text" value="Select Spacer"/> <input type="button" value="v"/>	Gas Fill: <input type="text" value="Select Gap Fill"/> <input type="button" value="v"/>



Source: www.nfrc.org

WINDOWS

NFRC Website Product Directory (continued)

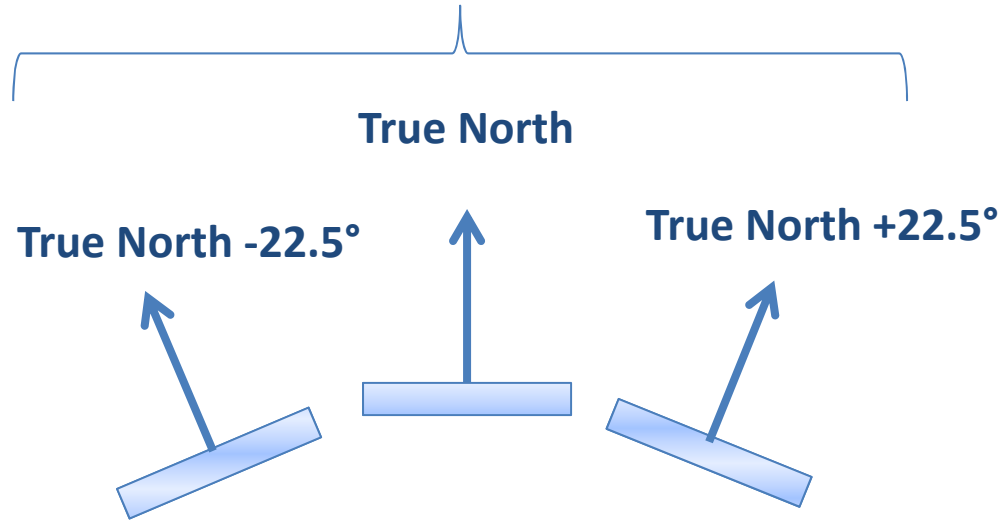
RATINGS INFORMATION														(Found 129 Products)
CPD #	Manufacturer Product Code	Frame / Sash Type	U-factor	SHGC	VT	Condensation Resistance	Glazing Layers	Low-E	Gap Widths	Spacer	GapFill	Grid	Divider	Tint
MIL-A-197-00354-00001	3mm Air 5mm Air 5mm	VH/VH	0.26	0.30	0.33	63	3		0.438,2.53	CU-D	Fill 1: AIR (100),Fill 2: AIR (100)	G	1.500000	CL
MIL-A-197-00357-00001	3mm Air 5mm Air 6mm	VH/VH	0.25	0.30	0.32	63	3		0.5,2.454	CU-D	Fill 1: AIR (100),Fill 2: AIR (100)	G	1.500000	CL
MIL-A-197-00368-00001	Lami Air Lami Air Lami	VH/VH	0.26	0.30	0.36	62	3		0.312,2.463	CU-D	Fill 1: AIR (100),Fill 2: AIR (100)	G	0.750000	CL
MIL-A-197-00380-00001	3mm Arg 5mm Air 6mm	VH/VH	0.25	0.30	0.32	64	3		0.5,2.454	CU-D	Fill 1: ARG/AIR (90/10),Fill 2: AIR (100)	G	1.500000	CL
MIL-A-197-00386-00001	3mm Arg Lami Air 5mm	VH/VH	0.25	0.30	0.32	64	3		0.406,2.522	CU-D	Fill 1: ARG/AIR (90/10),Fill 2: AIR (100)	G	1.500000	CL
MIL-A-197-00391-00001	Lami Arg Lami Air Lami	VH/VH	0.25	0.30	0.36	63	3		0.312,2.463	CU-D	Fill 1: ARG/AIR (90/10),Fill 2: AIR (100)	G	0.750000	CL
MIL-A-197-00660-00001	3mm Air 5mm Air 5mm	VH/VH	0.26	0.30	0.33	63	3		0.438,2.53	SU-D	Fill 1: AIR (100),Fill 2: AIR (100)	G	1.500000	CL
MIL-A-197-00663-	3mm Air 5mm Air 6mm	VH/VH	0.25	0.30	0.32	63	3		0.5,2.454	SU-D	Fill 1: AIR (100),Fill 2: AIR	G	1.500000	CL

Source: www.nfrc.org

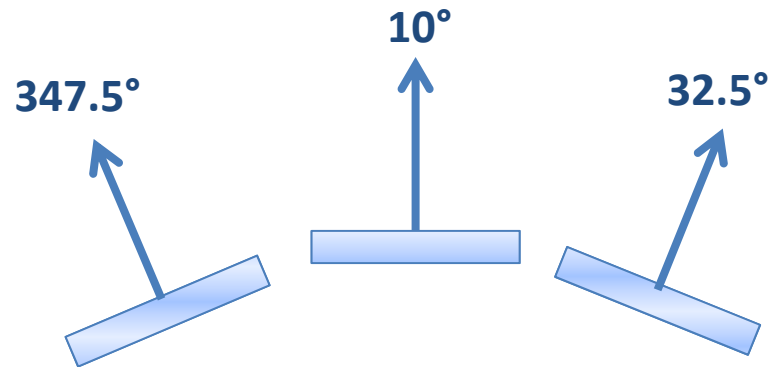
WINDOWS

North-facing
windows are
exempt

“North-facing”

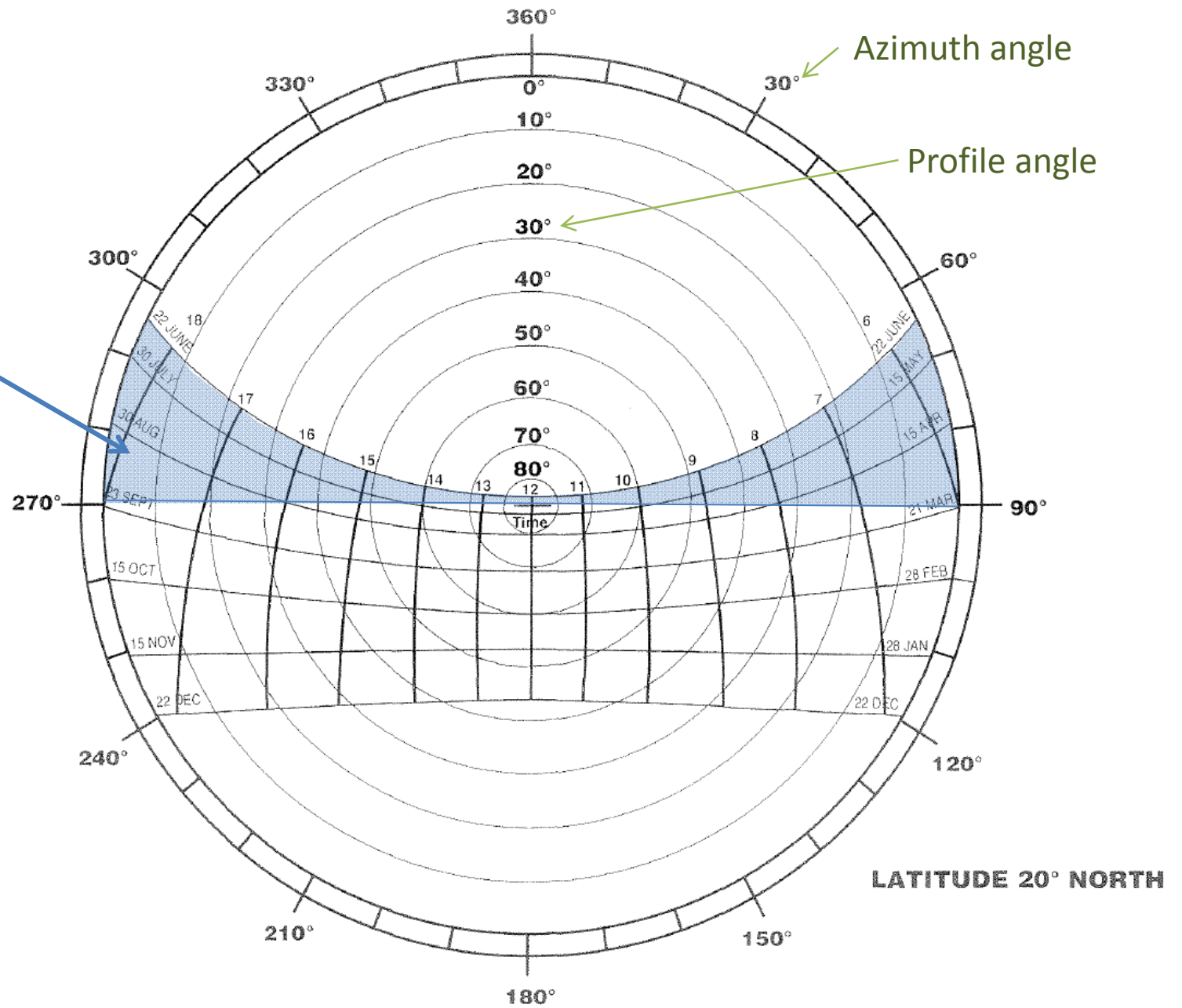


On magnetic compass in Hawaii



Sun Path Diagram

Hours when sun shines on north wall

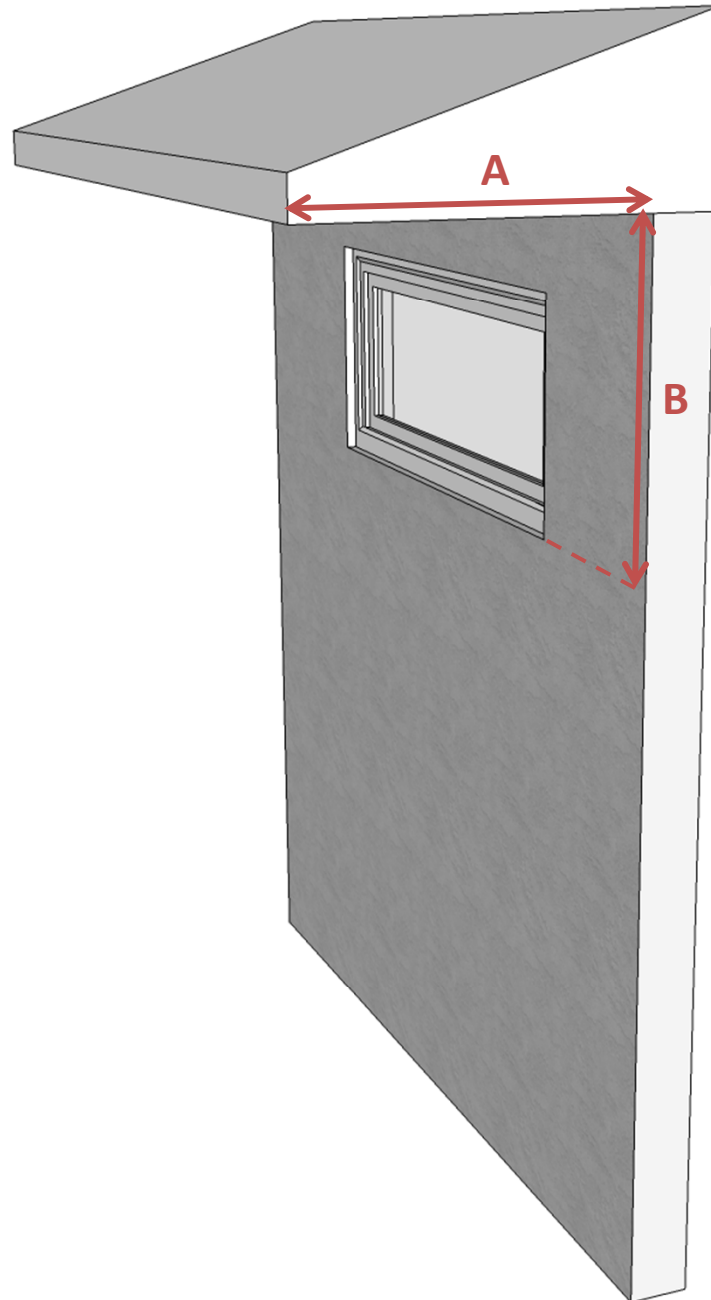


Source: Hawaiian Design, Strategies for Energy Efficient Architecture.

Available at <http://energy.hawaii.gov/resources/hawaii-state-energy-office-publications>

WINDOWS

Overhang shading compliance (402.3)



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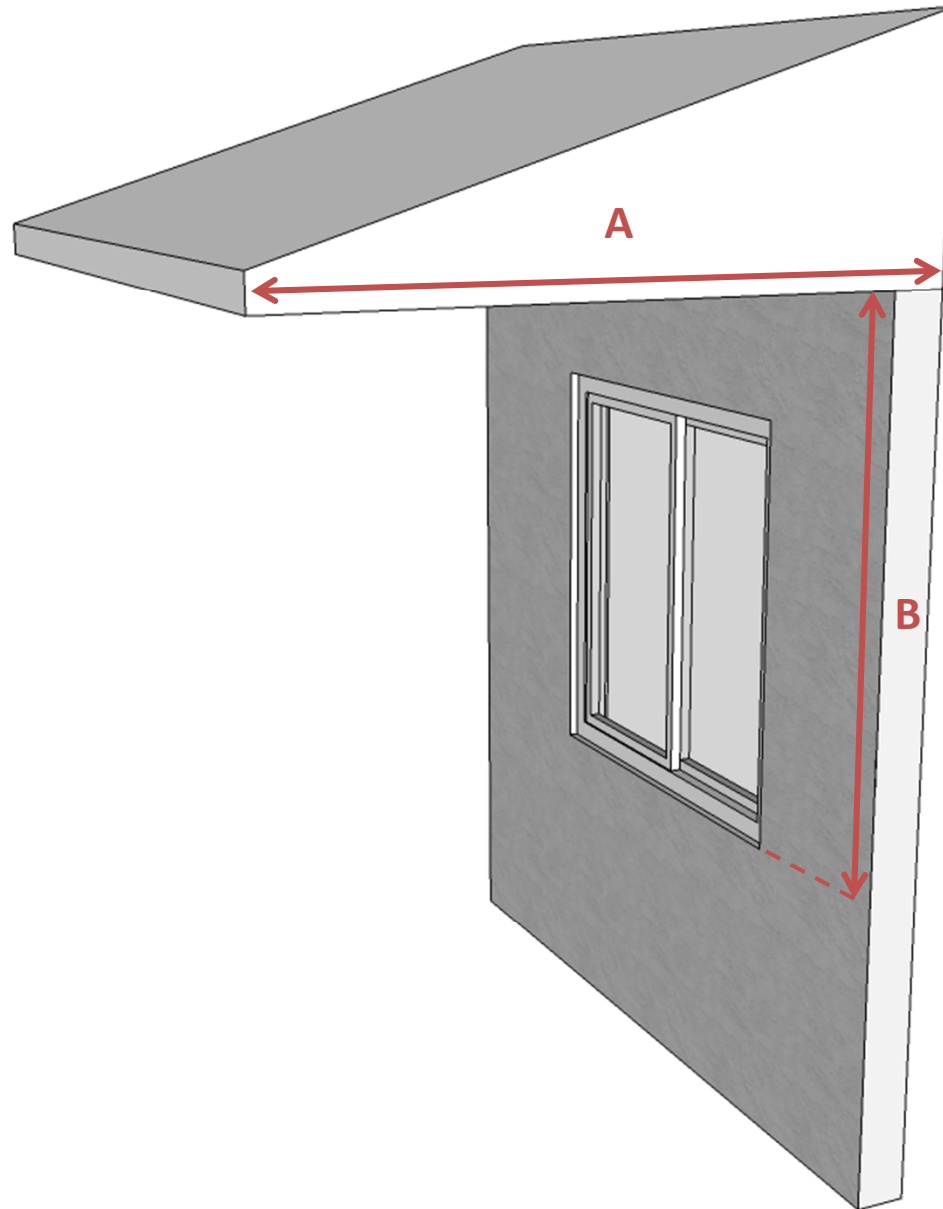
$$A/B \geq 1.0$$

Example:
If **B** = 30"
and **A** is ≥ 30 "

Then clear glass complies

WINDOWS

Overhang shading compliance (402.3)



RESIDENTIAL Envelope

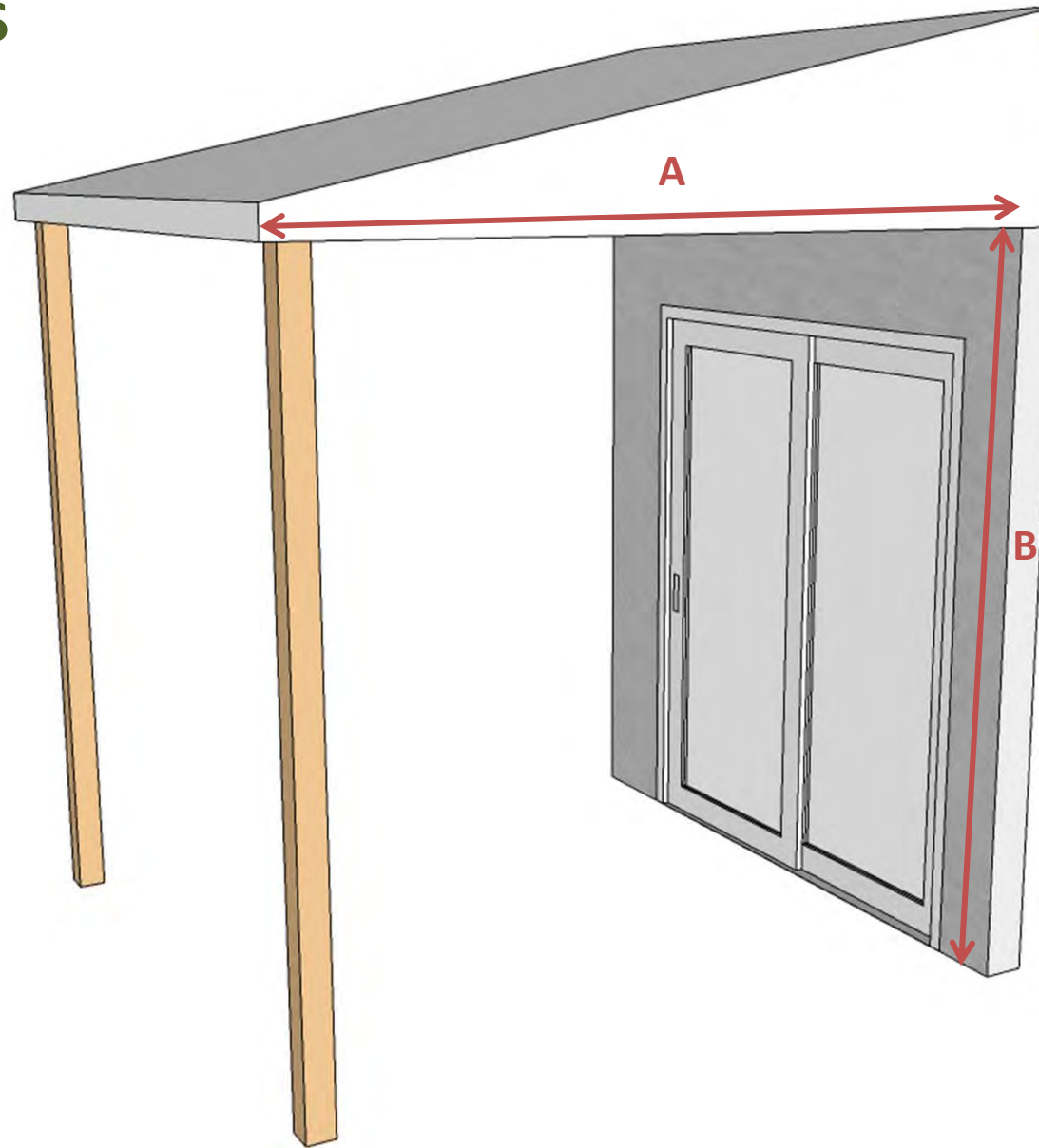
$$A/B \geq 1.0$$

Example:
If **B** = 5 ft
and **A** is ≥ 5 ft

Then clear glass complies

WINDOWS

Overhang shading compliance (402.3)



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$$A/B \geq 1.0$$

Example:
If **B** = 8 ft
and **A** is \geq 8 ft

Then clear glass complies

Windows Spreadsheet Compliance Option

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Hawaii Area-Weighted Average SHGC Template

- Window area
- Orientation
- SHGC
- Overhang dimensions (if any)
- % window covered by screens

Calculates
weighted-
average SHGC

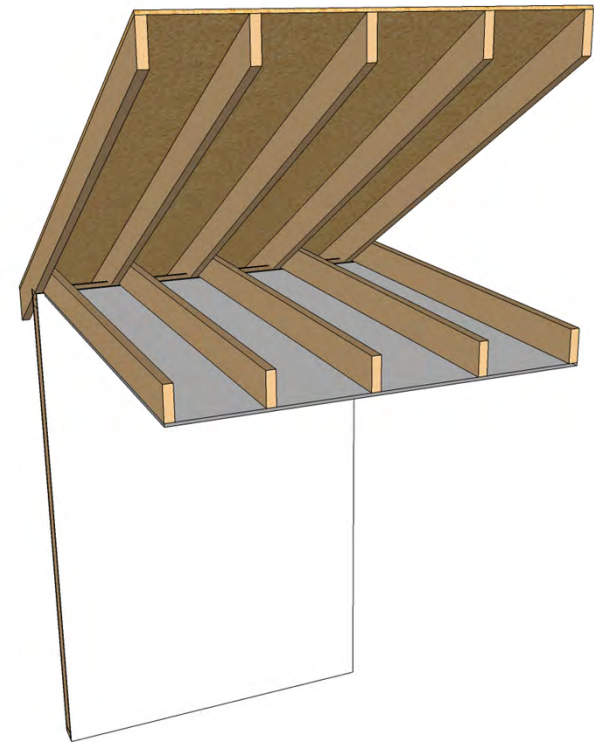
Window ID	Orientation of Window	Height (inches)	Width (inches)	Window Area (inches ²)	Exemptions applied	Glazing Material	Window SHGC	A	B	Projection Factor	Actual SHGC
1	South Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
2	North Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
3	East Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
4	West Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
5	South Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
6	North Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
7	East Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
8	West Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
9	South Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
10	North Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
11	East Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
12	West Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
13	South Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
14	North Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
15	East Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
16	West Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
17	South Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
18	North Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
19	East Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85
20	West Facing	80	80	6400	None	None	0.85	0.85	0.85	1.00	0.85

Spreadsheet and instructions at:
<http://energy.hawaii.gov/programs/achieving-efficiency/hawaii-energy-building-code>

Roof - Attic

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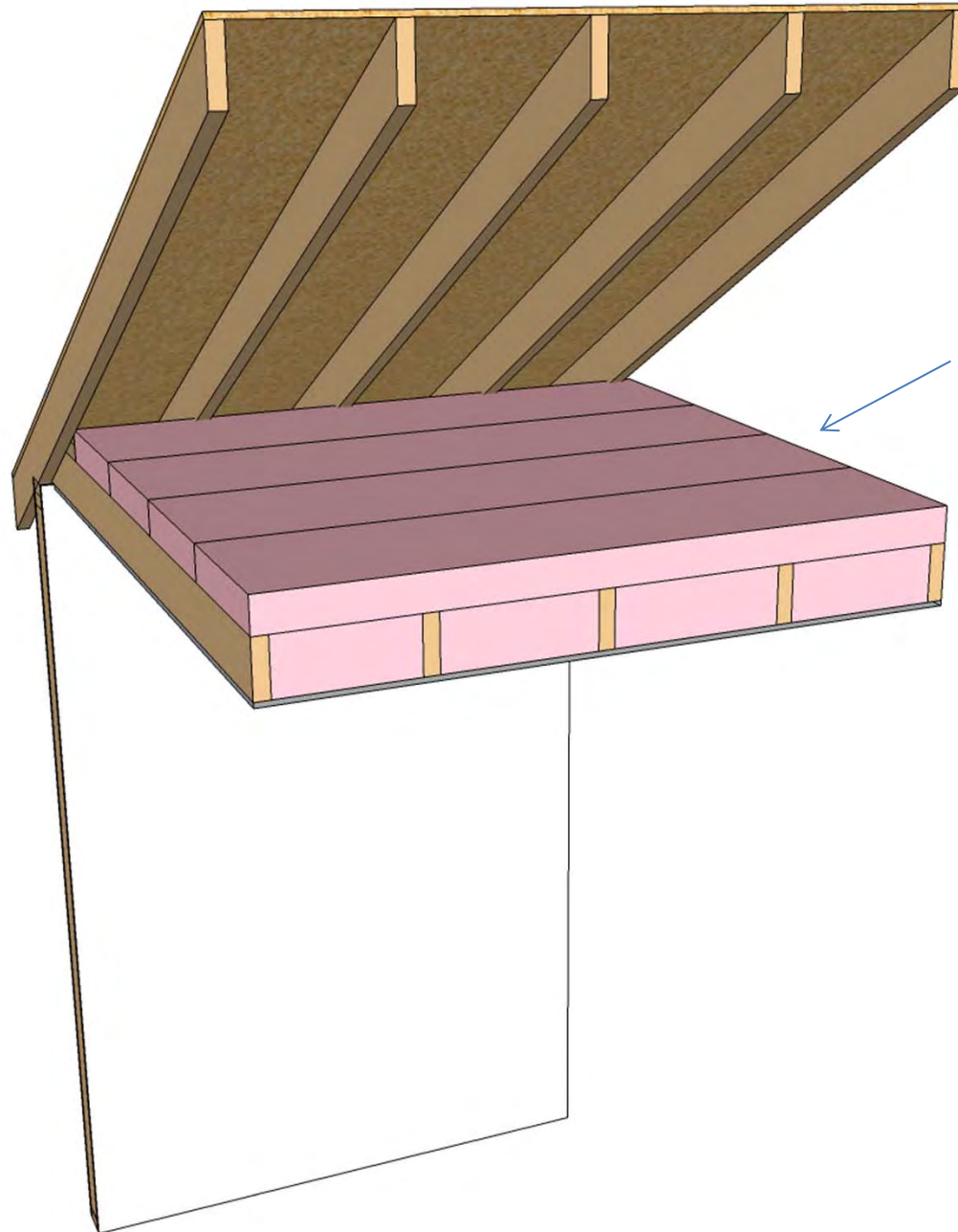
- Attic
 - R-30 at ceiling
 - Hawaii alternatives
 - 1. R-19 under roof
 - 2. Radiant barrier + extra ventilation
 - Baffled ridge vent
 - Solar power exhaust fan
 - 1/150 vent area
 - 3. Radiant barrier + cool roof
 - 4. Roof heat gain factor (RHGF) ≤ 0.05



ATTIC

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R-value
compliance
option
(402.1.1)



R-30 ceiling insulation

Typical options:

- Fiberglass batt
- Blown cellulose
- Blown fiberglass

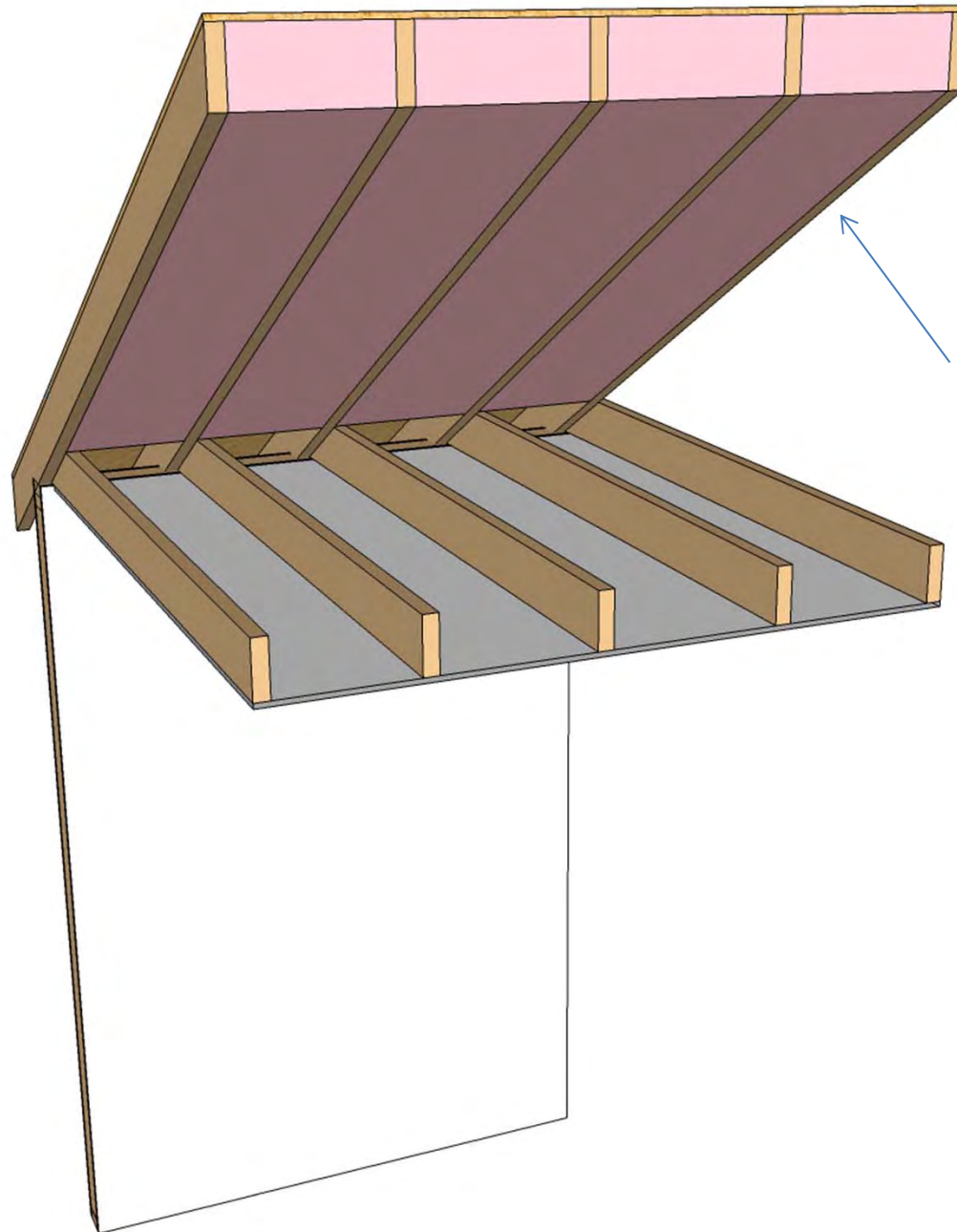
9 ½ in. typical thickness

For blown insulation,
installer posts R-value
certification at job site
(303.1.1)

ATTIC

Hawaii
Exception

Design
Option 1
(402.1.6)



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**R-19 insulation
under roof**

- Typical options:
- Fiberglass batt
 - Spray foam

5 ½ in. typical thickness

For spray insulation,
installer posts R-value
certification at job site
(303.1.1)

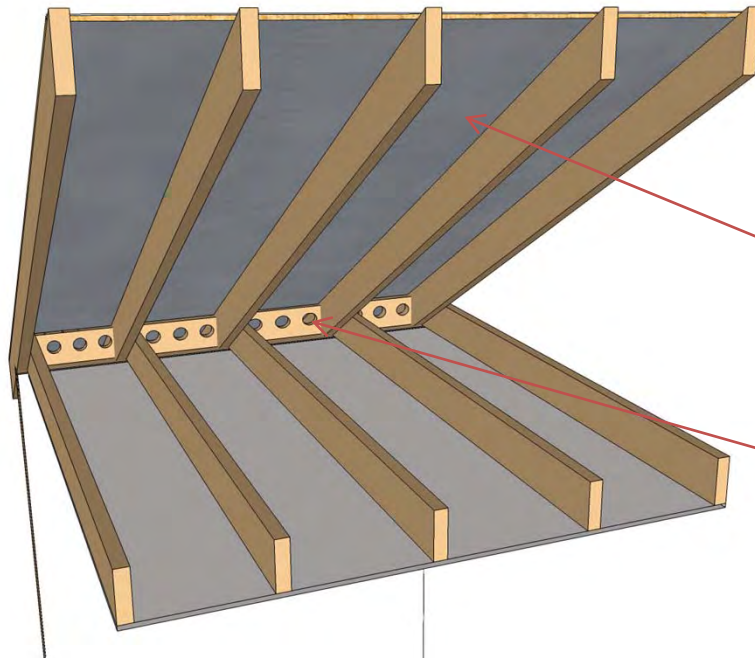
ATTIC

Hawaii
Exception

Design
Option 2
(402.1.6)

Radiant
Barrier +
Ventilation

RESIDENTIAL
Envelope



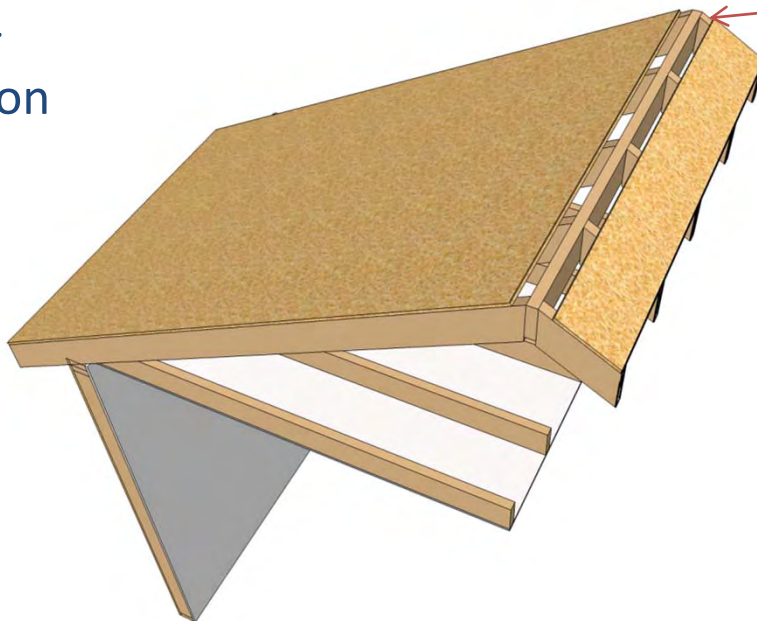
Radiant barrier
under roof

+

Eave or soffit
inlet vents

+

Outlet Option #1
Baffled ridge vent



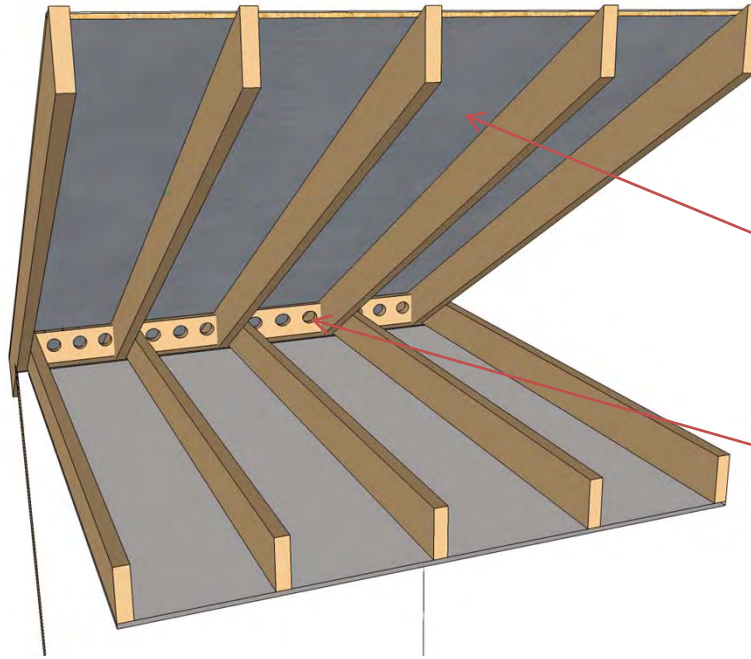
Source: www.owenscorning.com

ATTIC

Hawaii
Exception

Design
Option 2
(402.1.6)

Radiant
Barrier +
Ventilation



RESIDENTIAL
Envelope

Radiant barrier
under roof

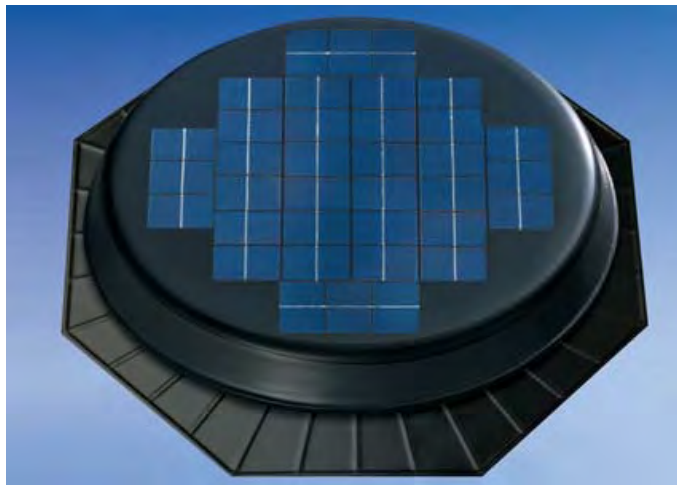
+

Eave or soffit
inlet vents

+

Outlet Option #2

Solar-power
exhaust fan

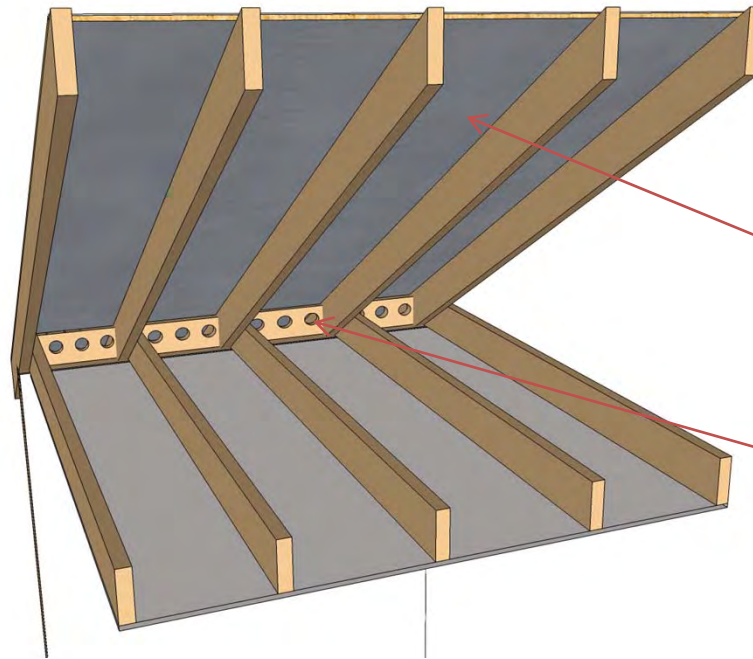


ATTIC

Hawaii
Exception

Design
Option 2
(402.1.6)

Radiant
Barrier +
Ventilation



RESIDENTIAL
Envelope

**Radiant barrier
under roof**

+

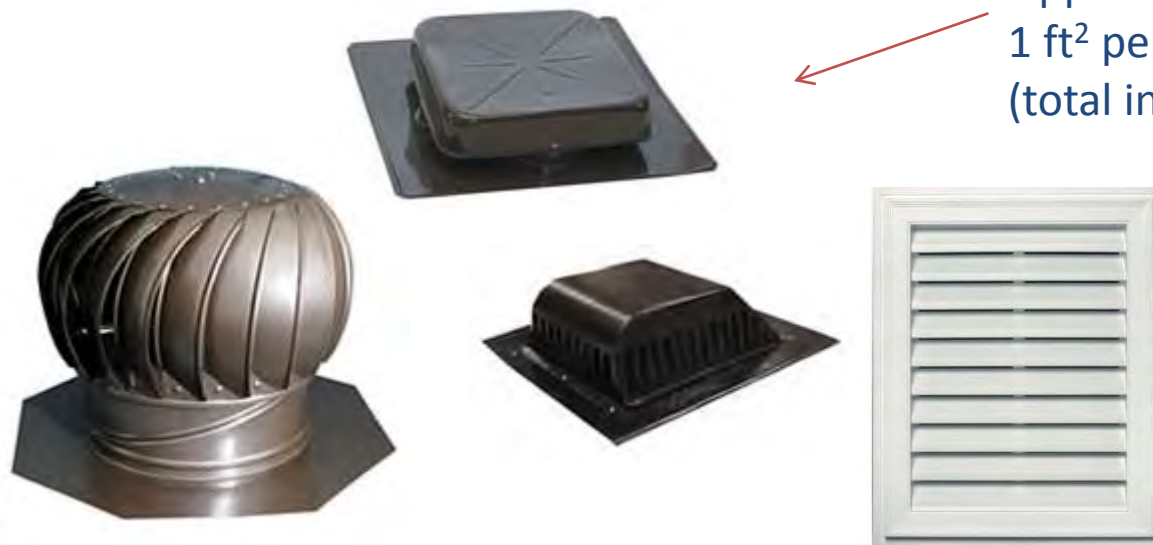
**Eave or soffit
inlet vents**

+

Outlet Option #3

Upper vent

1 ft² per 150 ft² attic
(total inlet + outlet)



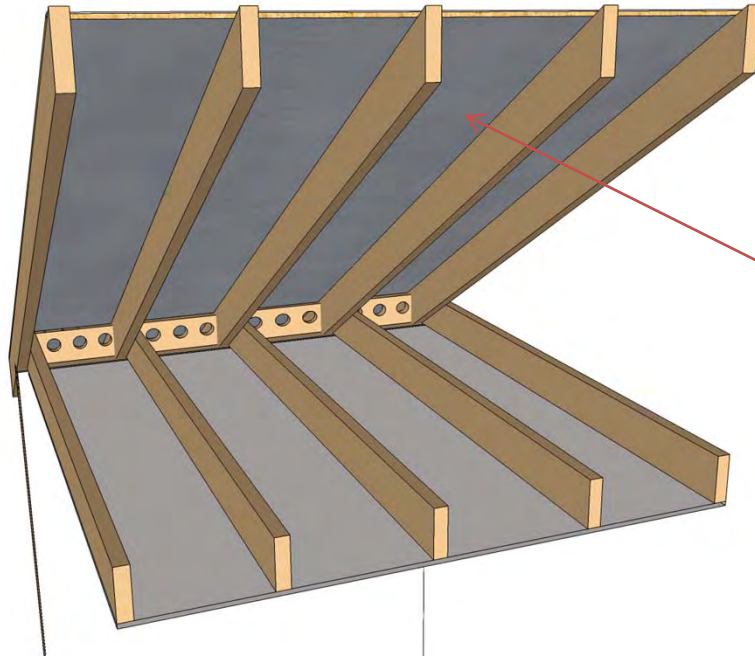
Source: www.owenscorning.com

ATTIC

Hawaii
Exception

Design
Option 3
(402.1.6)

Radiant
Barrier +
Cool Roof



RESIDENTIAL
Envelope

Radiant barrier
under roof

+

Cool roof

- 0.70+ initial reflectance
- 0.55+ extended reflectance
- 0.75+ infrared emittance



<http://www.whirlwindsteel.com>



<http://coolroofhawaii.com>

Cool Roof Example
Concrete roof tiles



www.hansonrooftile.com

Directory of Rated Products

Rated Products Directory: Search Results [\[new search \]](#) [\[print friendly view \]](#) [\[export \]](#)

(last updated 12 Oct 2012 12:48 CDT)

Showing Search Results for:

Product Type: Metal
Init. Solar Reflect.: $\geq .70$
Init. Therm. Emit.: $\geq .75$

[previous](#) | [1](#) | [next](#)

(showing records 1 - 25 of 29)


25 Records per Page



CRRC Prod. ID	Manufacturer Information (sorted +)	Brand	Model	Color Category	Product Type	Solar Reflect.		Therm Emit.		SRI ⓘ		Slope Application	Note about Ratings
						init	3 yr	init	3 yr	init	3 yr		
0840-0001	American Buildings Company Jeff Walsh (334-688-2407)	American Buildings - Metal Roof Panel	Regal White	Bright White	Metal	0.72	0.68	0.86	0.83	87	81	Low/Steep	
0638-0009	ATAS International, Inc Robert Goodhart (610-395-8445)	ATAS Roofing Products	ATAS Bone White, ATAS #26	Bright White	Metal	0.70	0.67	0.83	0.83	84	80	Low/Steep	ⓘ
0870-0001	Berridge Manufacturing Company Rob Hinojosa (210-650-3050)	Berridge Standing Seam Metal Roofing	Natural White	Bright White	Metal	0.77	0.71	0.82	0.85	95	86	Low/Steep	
0756-0001	Butler Manufacturing, A	Butler Roof Panel	Solar White	Bright White	Metal	0.71	0.68	0.85	0.81	86	81	Low/Steep	

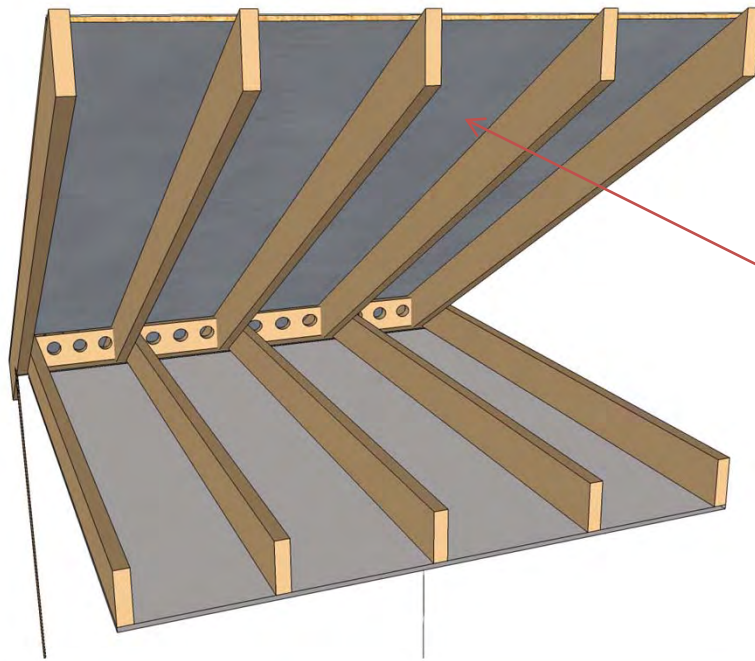
<http://www.coolroofs.org/products/search.php>

CRRC Product Label Example

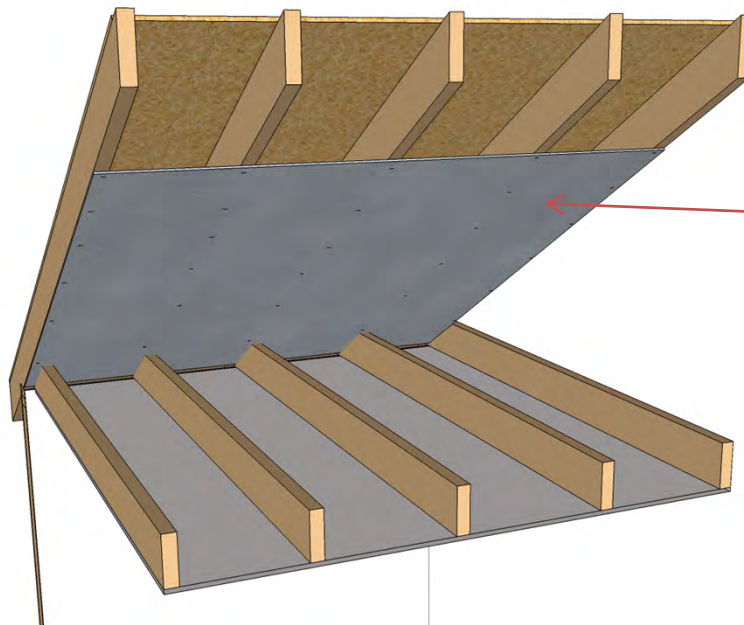
		<u>Initial</u>	<u>Weathered</u>
	Solar Reflectance Thermal Emittance	0.88 0.87	0.68 0.89
	Rated Product ID Number		0001
	Licensed Seller ID Number		0896
	Classification		Production Line
<p>Cool Roof Rating Council ratings are determined for a fixed set of conditions, and may not be appropriate for determining seasonal energy performance. The actual effect of solar reflectance and thermal emittance on building performance may vary.</p> <p>Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.</p>			

ATTIC

Some
radiant barrier
installation
options



Radiant barrier
laminated
under roof deck



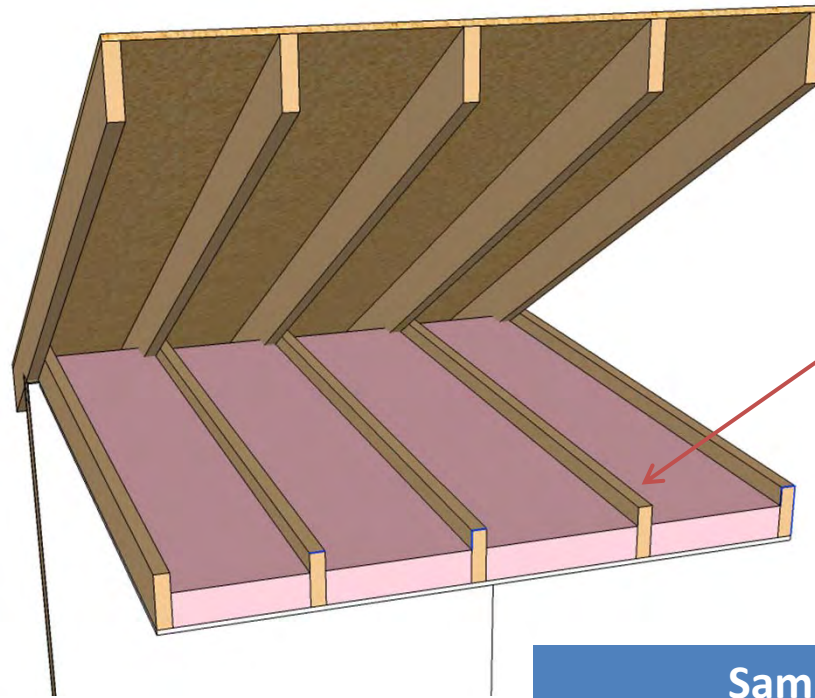
Radiant barrier
stapled to rafters

ATTIC

Hawaii
Exception

Design
Option 4
(402.1.6)

Roof Heat
Gain Factor
 ≤ 0.05



RESIDENTIAL
Envelope

Reflective roof

+

Ceiling insulation

$RHGF = U_r \cdot \alpha \cdot RB$
 U_r = roof U-factor
 α = absorptivity (1 – reflectance)
 RB = 0.33/1.0 with/without
 radiant barrier

Sample Combinations	
Ceiling Insulation R-Value (U-factor)	Minimum Roof Reflectance
R-11 (U-0.091)	45%
R-13 (U-0.081)	40%
R-15 (U-0.069)	30%
R-19 (U-0.053)	7%

U-factors per ASHRAE Standard 90.1-2010 Table A2.4



Which is coolest?

“Coastal Tan” **0.40 reflectance**



**EnergyStar for
steep-slope roof
Reflectance $\geq 25\%$**



“Aged Cedar” **0.26 reflectance**



“Birchwood” **~0.10 reflectance**



More Examples of Reflective Pigments

R=0.41	R=0.44	R=0.44	R=0.48	R=0.46	R=0.41
<i>black</i>	<i>blue</i>	<i>gray</i>	<i>terracotta</i>	<i>green</i>	<i>chocolate</i>
R=0.04	R=0.18	R=0.21	R=0.33	R=0.17	R=0.12

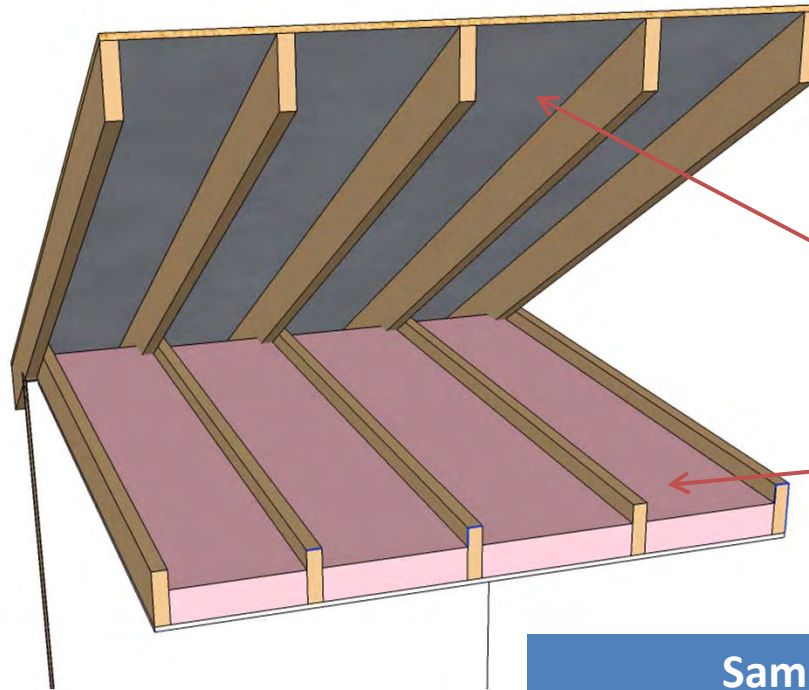
http://www.pge.com/includes/docs/pdfs/myhome/saveenergymoney/rebates/cool_roof_information_brief.pdf

ATTIC

Hawaii
Exception

Design
Option 4
(402.1.6)

Roof Heat
Gain Factor
 ≤ 0.05



RESIDENTIAL
Envelope

Reflective roof

+

Radiant barrier

+

Ceiling insulation

Sample Combinations	
Ceiling Insulation R-Value (U-factor)	Minimum Roof Reflectance
R-5 (U-0.20)	25%
R-6 (U-0.16)	5%

$RHGF = U_r \cdot \alpha \cdot RB$
 U_r = roof U-factor
 α = absorptivity (1 – reflectance)
 RB = 0.33/1.0 with/without
 radiant barrier

U-factors per ASHRAE Standard 90.1-2010 Table A2.4

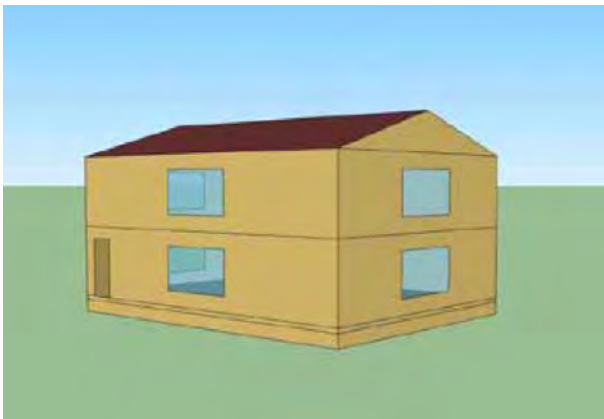
Attic Options

Energy Simulation Results

RESIDENTIAL
Envelope

Roof Alternatives

Roof Alternatives	Cooling kWh/yr	Difference
Option 1: baseline R-30	6,617	--
Option 2: ventilation + radiant barrier	7,222	9.1%
Option 3: radiant barrier + cool roof	6,842	3.4%
Option 4: RHGF = 0.05 (cool roof + R-3)	7,035	6.3%



EnergyPlus Model
2,400 ft², two-story house
Honolulu

Roof – Single Rafter (no attic)

RESIDENTIAL
Envelope

- Hawaii alternatives

1. Insulation

- R-19 between framing, or
- R-15 above deck

- ~~2. Radiant barrier + extra ventilation~~

- Impractical, requires upper/lower vents in each cavity

3. Radiant barrier + cool roof

4. Roof heat gain factor (RHGF) ≤ 0.05

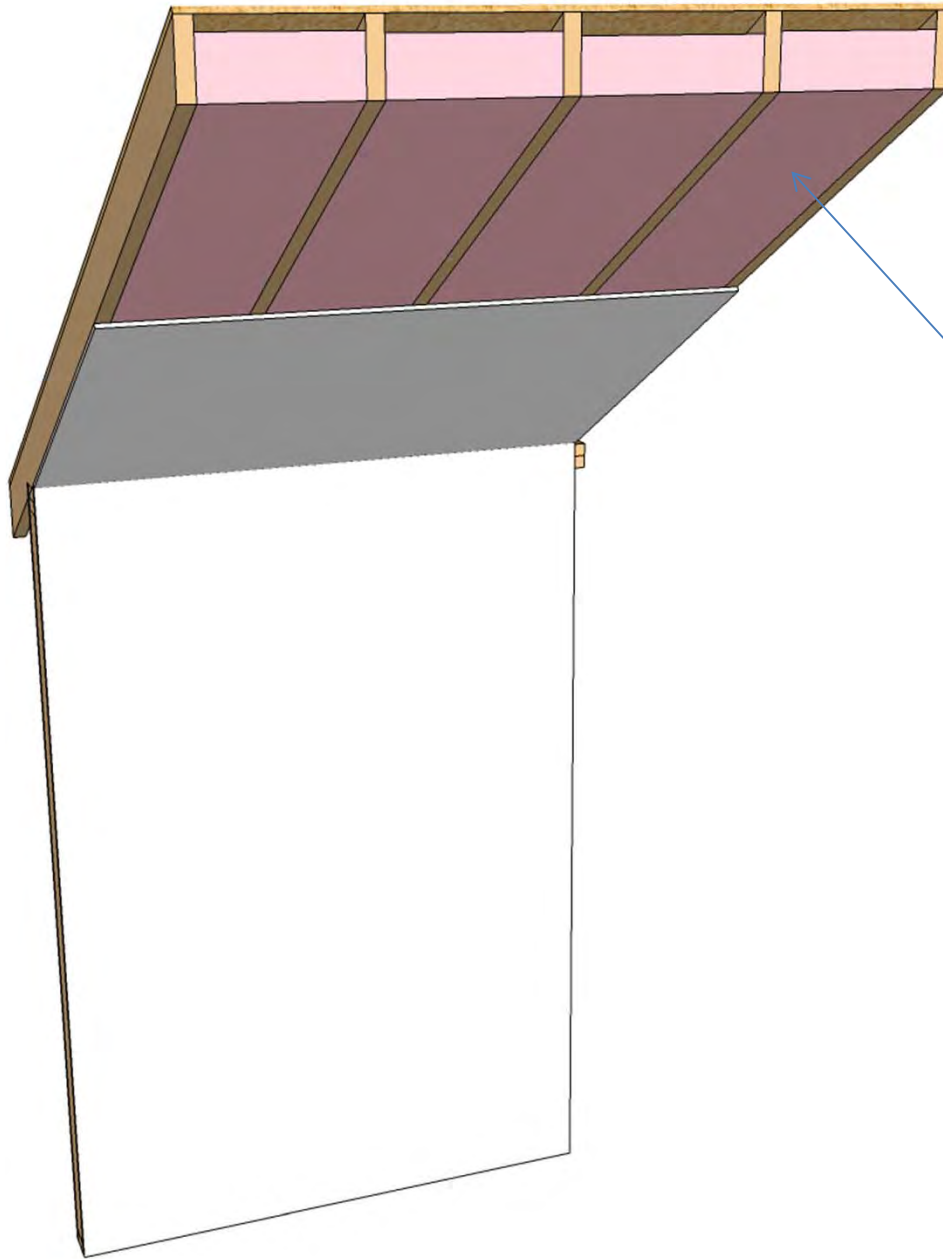
1. 70% + R-4
2. 40% + R-10
3. RB + 40% + R-2
4. RB + 25% + R-3



SINGLE- RAFTER ROOF

Hawaii
Exception

Design
Option 1
(402.1.6)



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Envelope

**R-19 insulation
between framing**

Typical options:

- Fiberglass batt
- Spray foam

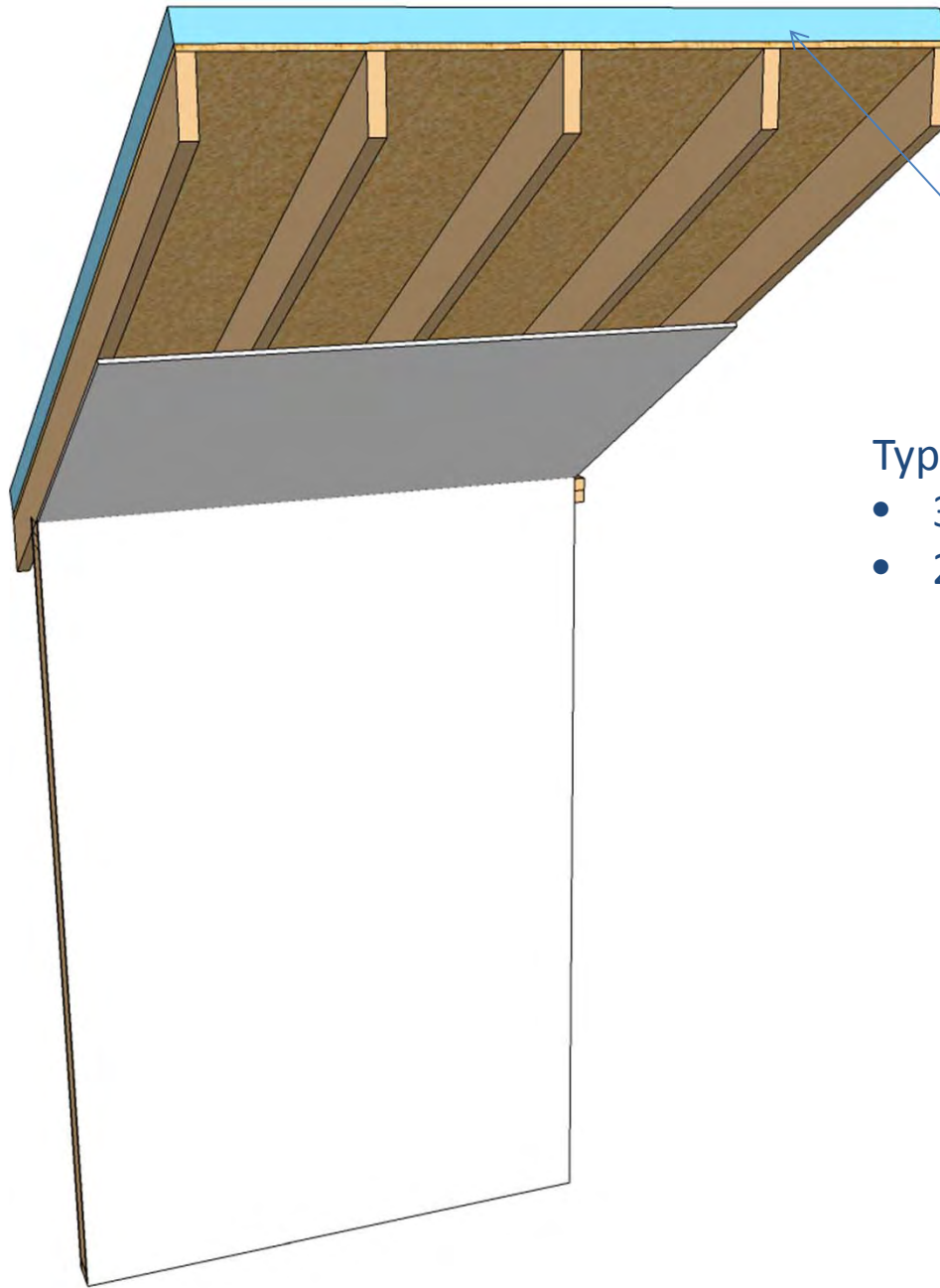
5 ½ in. typical thickness

For spray insulation,
installer posts R-value
certification at job site
(303.1.1)

SINGLE- RAFTER ROOF

Hawaii
Exception

Design
Option 1
(402.1.6)



RESIDENTIAL
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R-15 insulation
above deck

Typical options:

- 3 in. polystyrene
- 2.5 in. polyisocyanurate

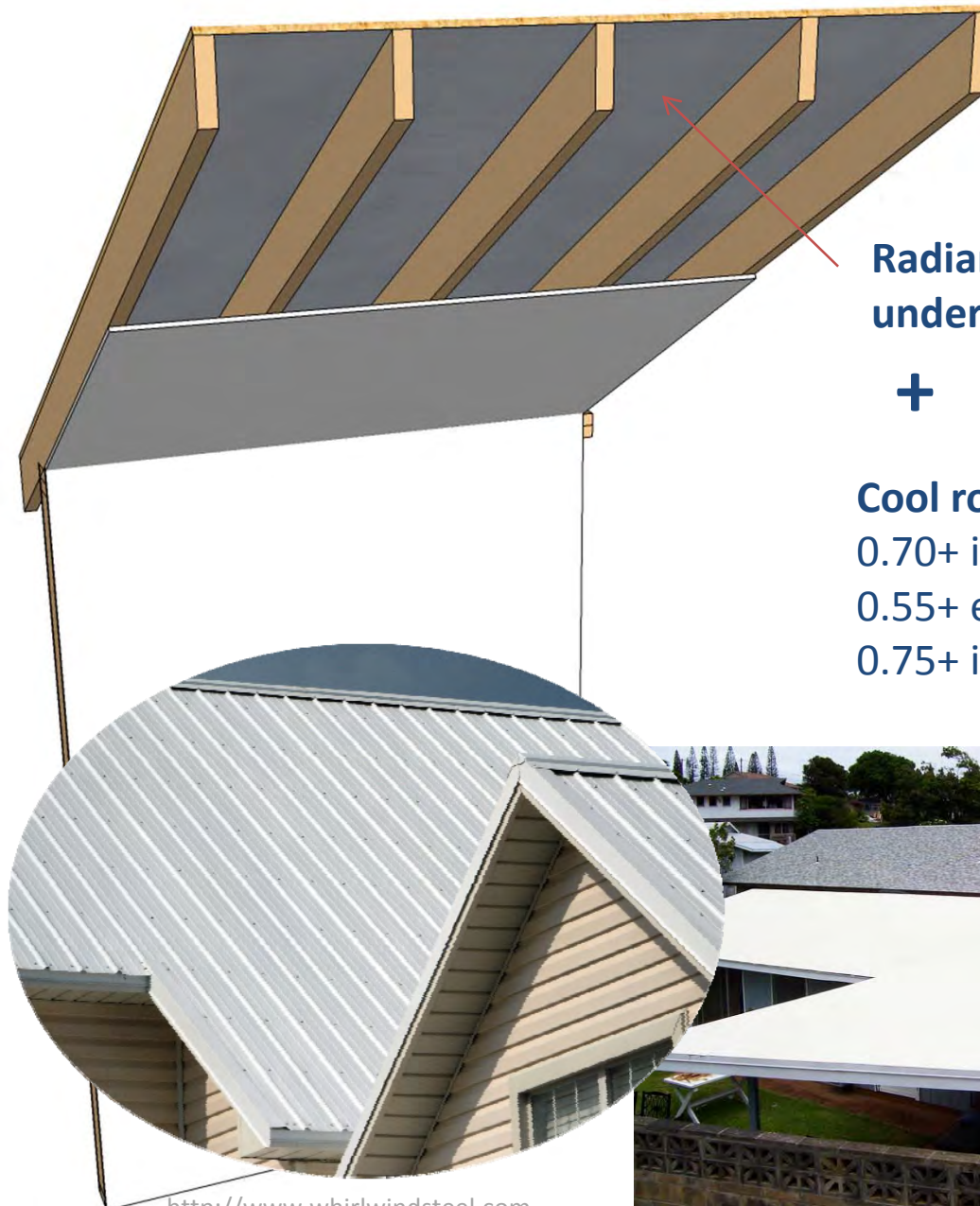
For spray insulation,
installer posts R-value
certification at job site
(303.1.1)

SINGLE- RAFTER ROOF

Hawaii
Exception

Design
Option 3
(402.1.6)

Radiant
Barrier +
Cool Roof



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Envelope

Radiant barrier
under roof

+

Cool roof
0.70+ initial reflectance
0.55+ extended reflectance
0.75+ infrared emittance

<http://www.whirlwindsteel.com>

<http://coolroofhawaii.com>

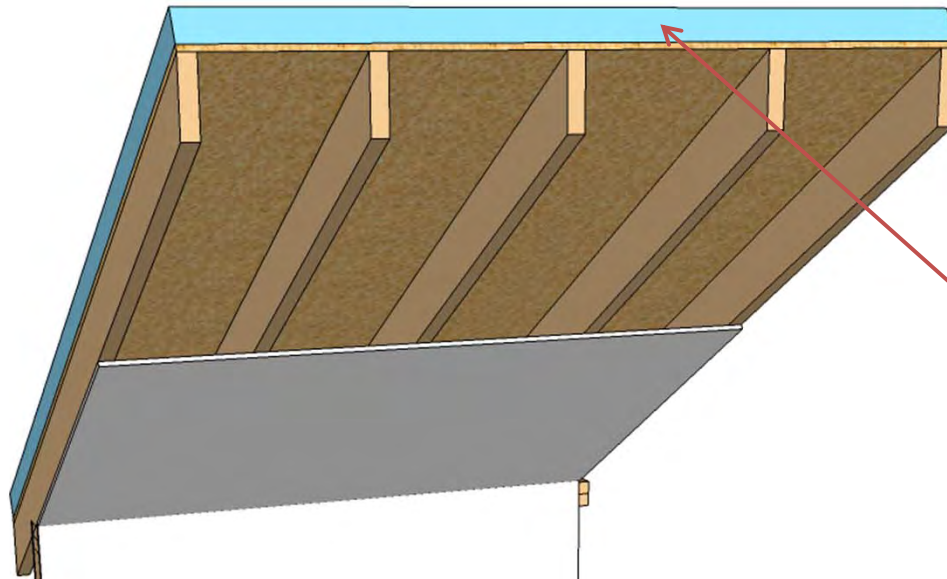
SINGLE- RAFTER ROOF

Hawaii
Exception

Design
Option 4
(402.1.6)

Roof Heat
Gain Factor
 ≤ 0.05

$RHGF = U_r \cdot \alpha \cdot RB$
 U_r = roof U-factor
 α = absorptivity (1 – reflectance)
 RB = 0.33/1.0 with/without
 radiant barrier



RESIDENTIAL
Envelope

Reflective roof

+

Roof insulation

Sample Combinations	
Roof Insulation R-Value (U-factor)	Minimum Roof Reflectance
R-4 (U-0.156)	70%
R-10 (U-0.081)	40%

U-factors per ASHRAE Standard 90.1-2010 Table A2.4

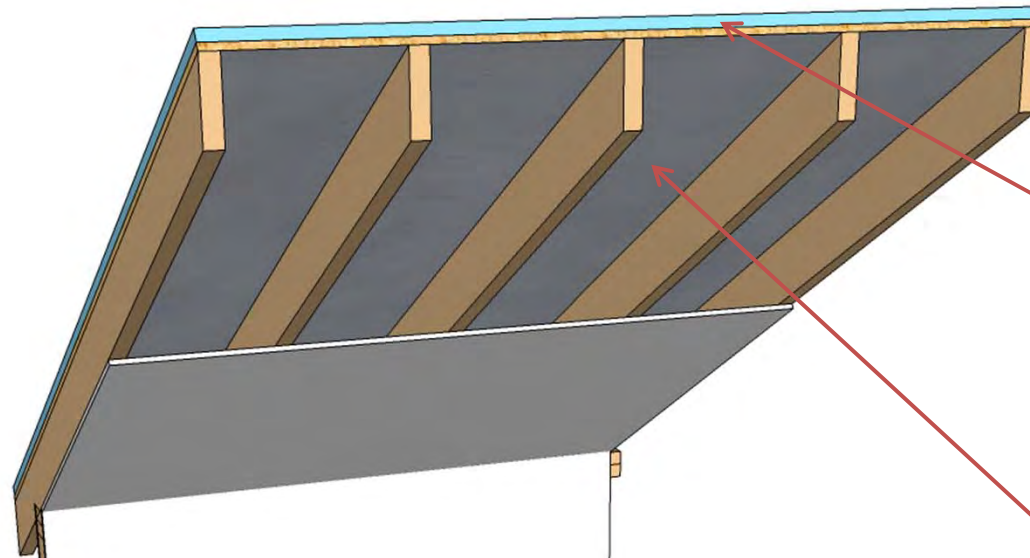
SINGLE- RAFTER ROOF

Hawaii
Exception

Design
Option 4
(402.1.6)

Roof Heat
Gain Factor
 ≤ 0.05

$RHGF = U_r \cdot \alpha \cdot RB$
 U_r = roof U-factor
 α = absorptivity (1 – reflectance)
 RB = 0.33/1.0 with/without
 radiant barrier



RESIDENTIAL
Envelope

Reflective roof

+

Roof insulation

+

Radiant barrier

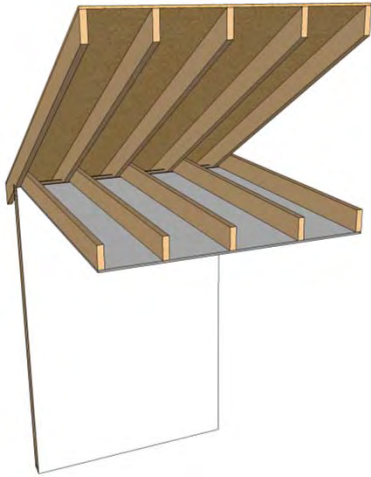
Sample Combinations	
Roof Insulation R-Value (U-factor)	Minimum Roof Reflectance
R-2 (U-0.227)	40%
R-3 (U-0.185)	25%

U-factors per ASHRAE Standard 90.1-2010 Table A2.4

Roof Summary

Attic

RESIDENTIAL
Envelope



Roof Reflectance	Selected Compliance Paths	Design Option
0.70 +	<ul style="list-style-type: none"> • Radiant barrier 	3
≥ 0.40	<ul style="list-style-type: none"> • R-13 ceiling insulation 	4
≥ 0.25	<ul style="list-style-type: none"> • R-19 ceiling insulation • Radiant barrier + R-5 ceiling insulation 	4 4
Any	<ul style="list-style-type: none"> • R-30 ceiling insulation • R-19 roof insulation • Radiant barrier + extra ventilation 	1 1 2

Roof Summary

Single-Rafter

RESIDENTIAL
Envelope



Roof Reflectance	Selected Compliance Paths	Design Option
0.70 +	<ul style="list-style-type: none"> • Radiant barrier • R-4 roof insulation 	3 4
≥ 0.40	<ul style="list-style-type: none"> • Radiant barrier + R-2 roof insulation • R-10 roof insulation 	4 4
≥ 0.25	<ul style="list-style-type: none"> • Radiant barrier + R-3 roof insulation 	4
Any	<ul style="list-style-type: none"> • R-19 insulation between framing • R-15 insulation above roof deck 	1 1

The background of the slide is a photograph of trees, likely a large, mature tree with thick branches and dense foliage. The image is overlaid with a semi-transparent green filter, which softens the colors and creates a monochromatic green palette. The text is positioned in the lower-left quadrant of the slide.

2009 IECC

AC RESIDENCE LIGHTING STRATEGIES

HIGH EFFICACY LIGHTING

Full-size fluorescent examples



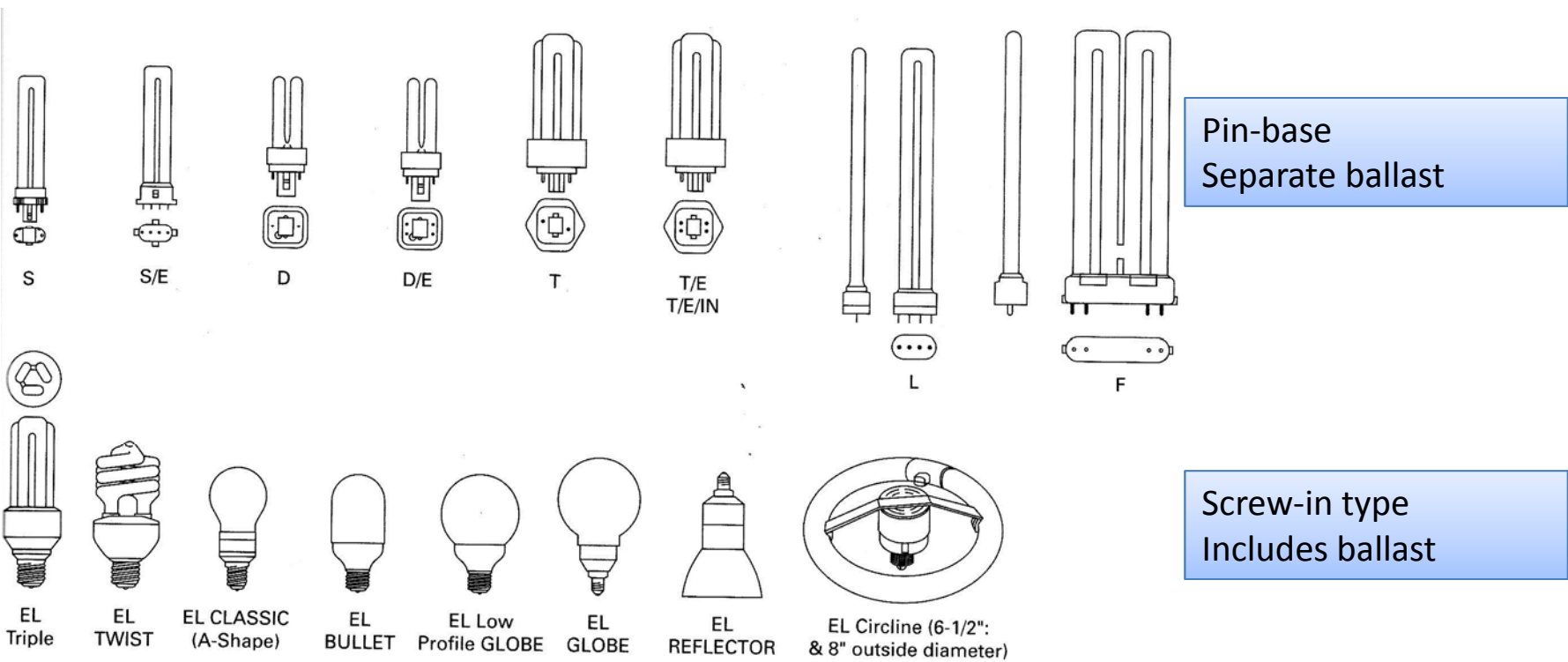
Source: DOE/NREL PIX17472



Source: DOE/NREL PIX17458

HIGH EFFICACY LIGHTING

Compact fluorescent lamps




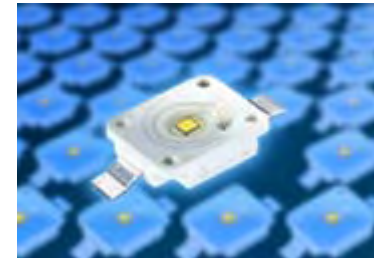
Pin-base
Separate ballast

Screw-in type
Includes ballast

Lifetime ~10,000 hours
Efficacy 50-60 LPW

Solid-State Lighting (SSL) Light Emitting Diode (LED) Lamps

- Long life
 - 35,000 – 50,000 hours
(if heat managed properly)
- Heat is mostly conductive, not radiant
 - Need heat sink 
 - Limits practical light output
- Fairly easy to focus light, put it where you need it



Source: www.osram-os.com

HIGH EFFICACY LIGHTING

LED downlight example



Source: DOE/NREL PIX20310



Source: DOE/NREL PIX20307

HIGH EFFICACY LIGHTING

LED track light example



Source: DOE/NREL PIX20311

HIGH EFFICACY LIGHTING

LED screw-base examples



Source: DOE/NREL PIX19375



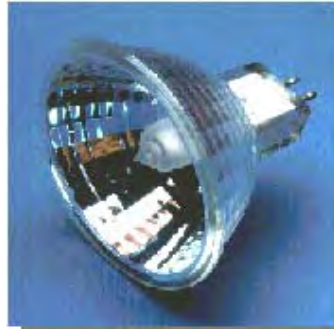
Source: DOE/NREL PIX19374

NON-COMPLYING LIGHTING

Incandescent
(including
halogen)



Source: DOE/NREL PIX19373



Livermore Firehouse lamp
burning since 1901
Long life, but low efficacy

Lighting Controls

Dimming

- Full-size fluorescent
 - Dimming ballast + special controller
- Compact fluorescent
 - Dimming ballast + special controller, or
 - Some self-ballasted lamps + incandescent dimmer
- LED
 - Some work with incandescent-type dimmers
 - Check with manufacturer
 - Others have dedicated dimmers



Source: www.lutron.com

2009 IECC

AC RESIDENCE MECHANICAL STRATEGIES

AC Residence Air Conditioning System Requirements

RESIDENTIAL
Systems

- Duct insulation



- Duct sealing



Source: www.energycodes.gov

- Duct testing



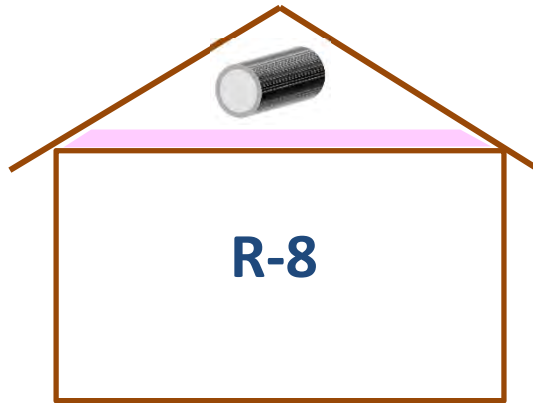
Source: DOE/NREL PIX04869



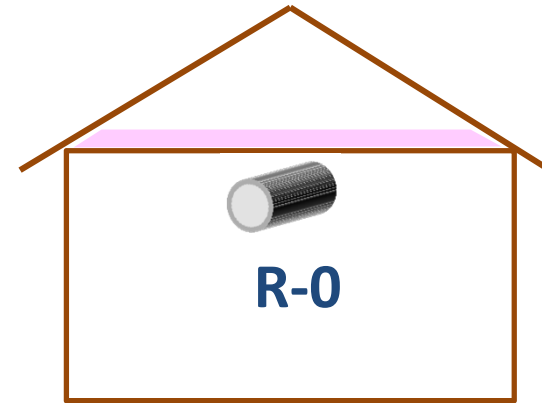
DUCT INSULATION

(403.2.1)

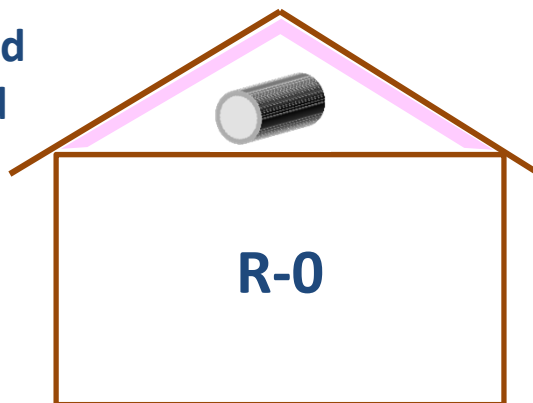
In attic



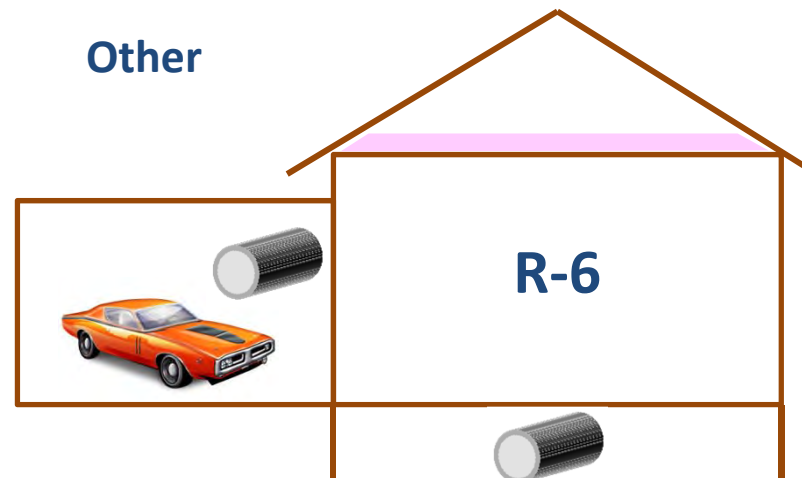
Within
thermal
envelope



In insulated
and sealed
attic



Other



DUCT INSULATION EXAMPLES

RESIDENTIAL
Systems



R-6
(~1.75" thick)



R-8
(~2.5" thick)

DUCT WITHIN THERMAL ENVELOPE EXAMPLES



Source: DOE/NREL PIX03067



Source: DOE/NREL PIX10076

Ducts Sealing (403.2.2)

- IRC M1601.4.1 Joints, seams and connections
 - Mechanically fastened and sealed
- 1. Sealing
 - Tape with UL mark “181 B-FX”
 - Mastic with UL mark “181 B-M”



Source: www.energycodes.gov

Ducts Sealing (403.2.2)

RESIDENTIAL
Systems

- IRC M1601.4.1 Joints, seams and connections

- Mechanically fastened and sealed

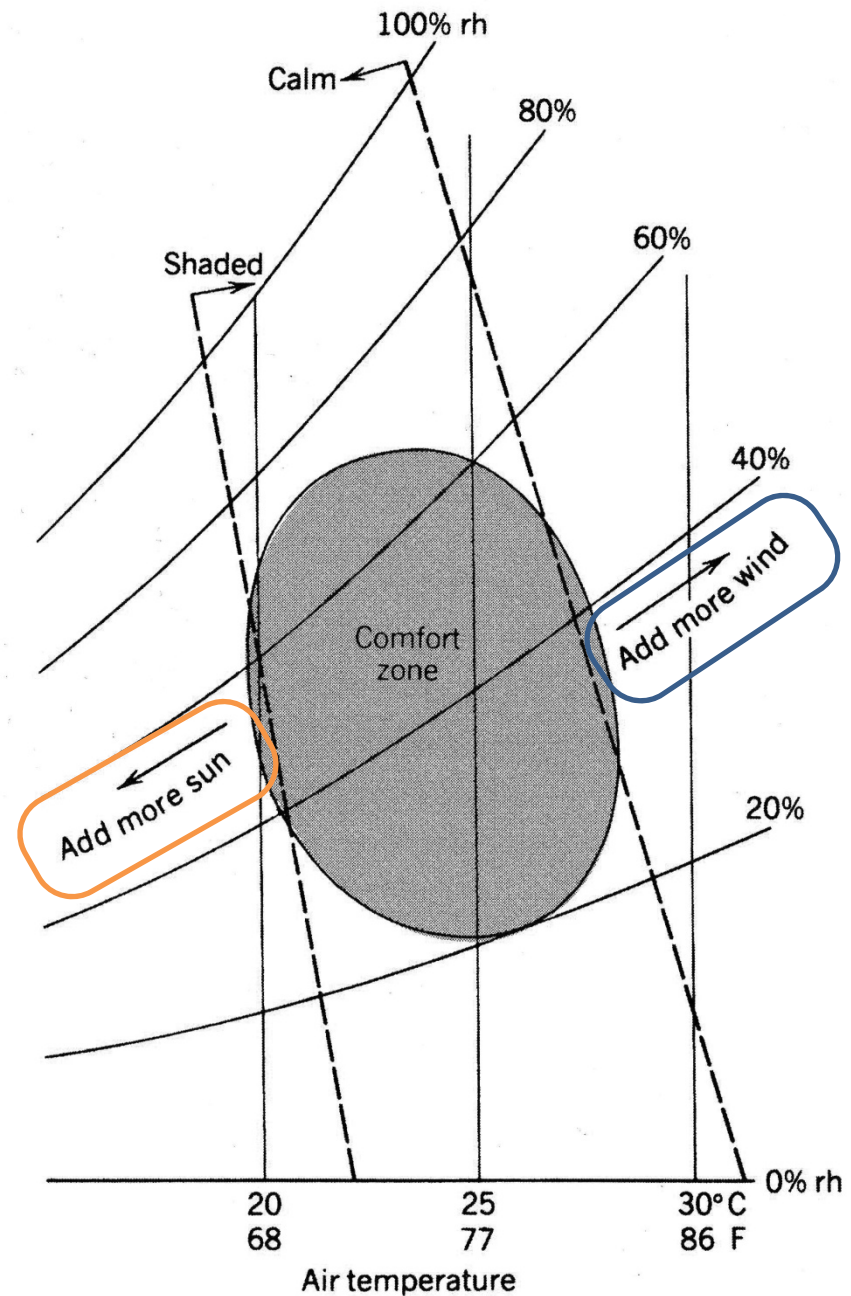
2. Mechanical fastening

- Flex duct
 - Mechanical fasteners with UL mark “181 B-C”
- Metallic duct
 - At least 1 inch overlap
 - At least three screws/rivets



AC Residence Beyond Code...

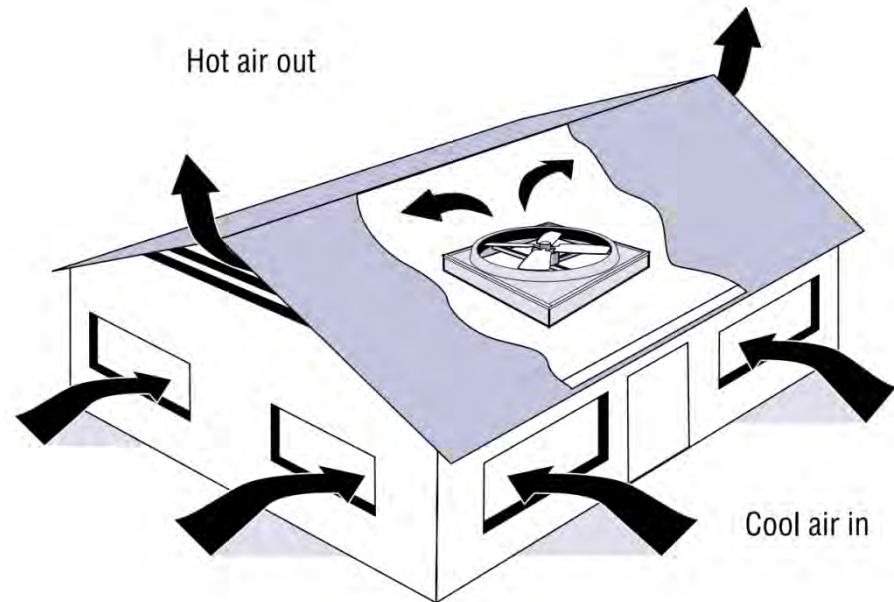
- Design for comfort
- Comfort zone
 - Shifts left when more radiant heat (e.g. sun) available
 - Shifts right when air movement is present



AC Residence Beyond Code...

RESIDENTIAL Systems

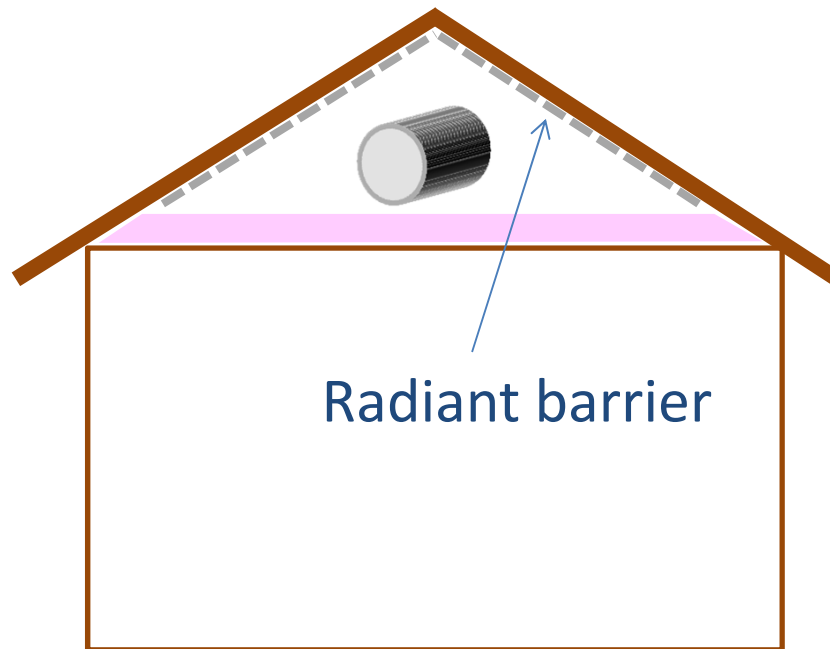
- Design for comfort to minimize need for AC
 - Shaded windows
 - Cool ceiling
 - Natural ventilation
 - Rain protection & security
 - Ceiling fans
 - Whole-house fan



Source: <http://www.nrel.gov/docs/fy99osti/26291.pdf>

AC Residence Beyond Code...

- Efficient duct systems
 - Minimize number of bends
 - Minimize length
 - Radiant barrier above attic ducts



AC Residence Beyond Code...

RESIDENTIAL
Systems

- Efficient AC systems
 - “Right sizing”
 - Variable capacity fan and compressor
 - Ductless split system



<http://energy.gov/energysaver/articles/ductless-mini-split-air-conditioners>



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AC RESIDENCE WRAP UP

Residential Wrap Up

- Walls
- Windows
- Roof
- Lighting
- AC system
- Beyond code...



2009 IECC

SMALL COMMERCIAL PROJECT INTRODUCTION

Learning Objectives

Nonresidential

COMMERCIAL

- Identify envelope design priorities for heat-gain reduction
- Determine compliance for a small commercial HVAC system
- Identify energy efficient HVAC strategies for a small commercial system
- Evaluate interior lighting power compliance and identify efficient lighting design strategies
- Evaluate exterior lighting power compliance and efficient design strategies

Small Commercial Project Example

Walls

Roof

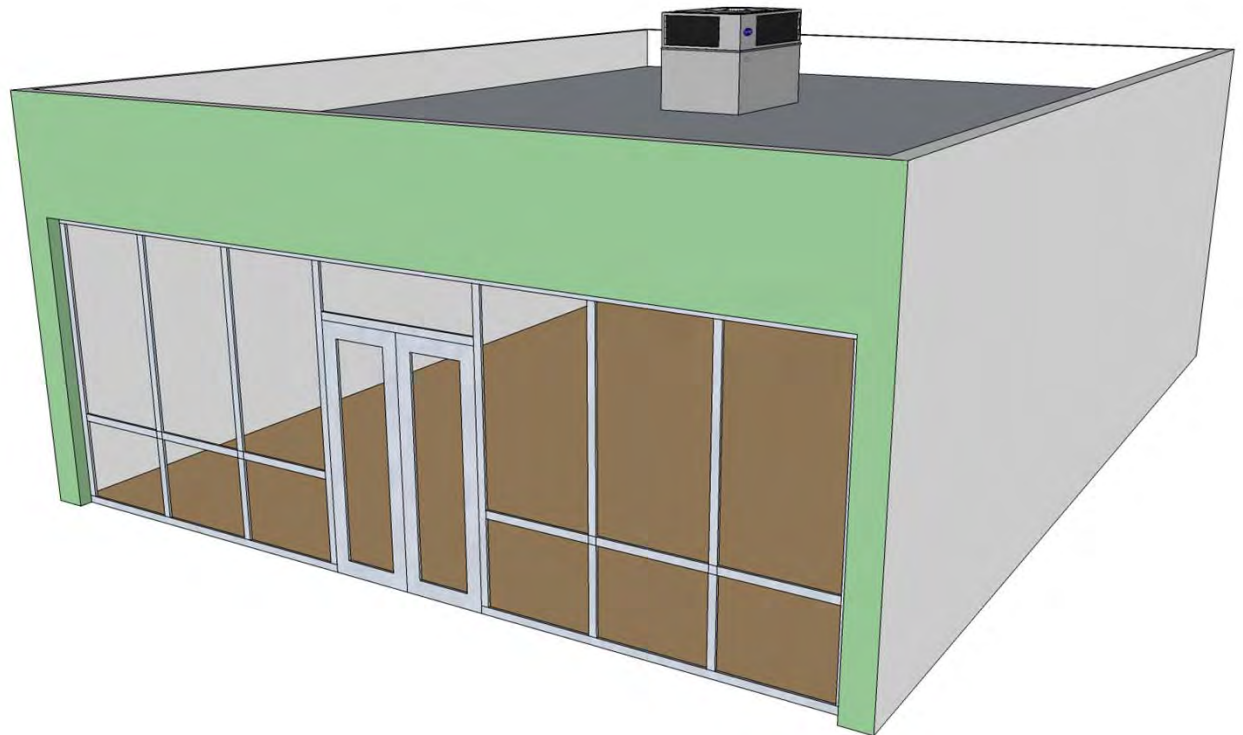
Window area

Window SHGC

HVAC

Interior lighting

Exterior lighting





2009 IECC

SMALL COMMERCIAL ENVELOPE

Floor

COMMERCIAL
Envelope

- Reminder... no floor insulation requirements
 - Slab-on-grade
 - Raised floor
 - Basement walls
 - Crawlspace walls

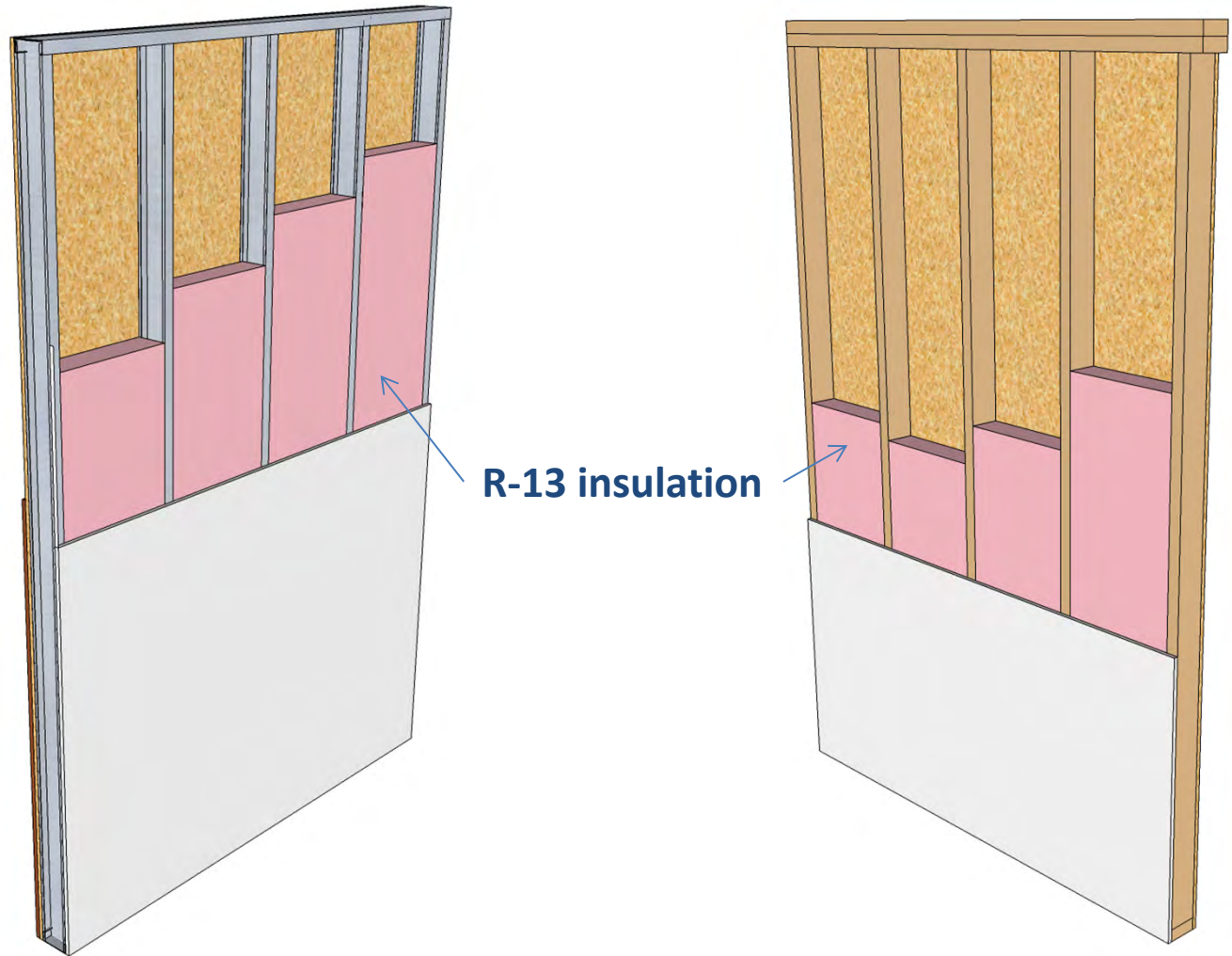
FRAME WALLS

R-value compliance option (502.1)

COMMERCIAL Envelope

Steel frame

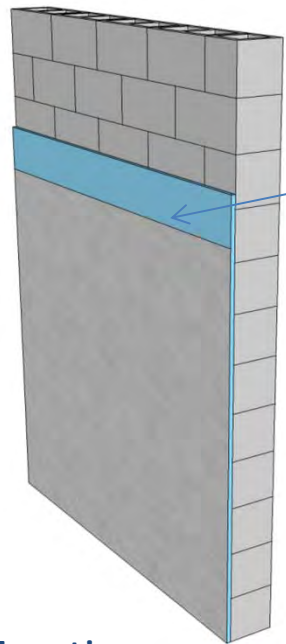
Wood frame



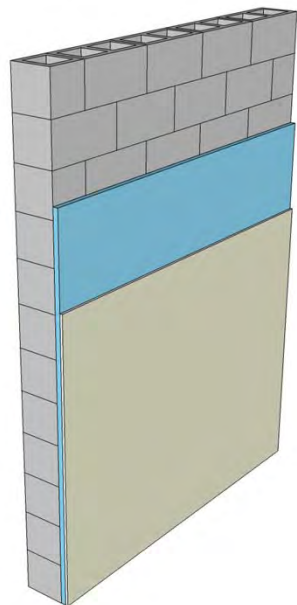
MASS WALL

R-value compliance option (502.1)

Group R Buildings



R-5.7 insulation (interior or exterior)

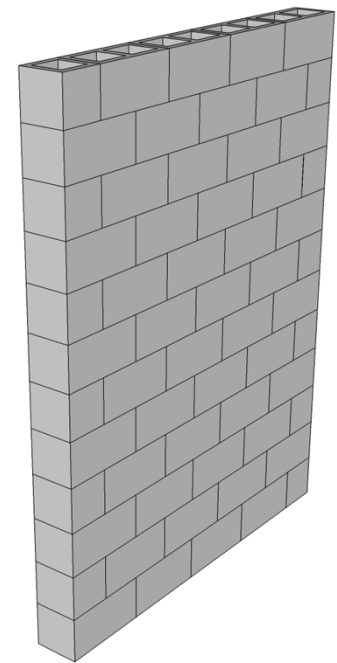


Typical R-5.7 options:

- 1.5 in. extruded polystyrene foam
- 1 in. polyisocyanurate foam

COMMERCIAL Envelope

All Other Commercial Buildings



No insulation required

ROOF INSULATION BELOW DECK

R-value
compliance
option
(502.2)

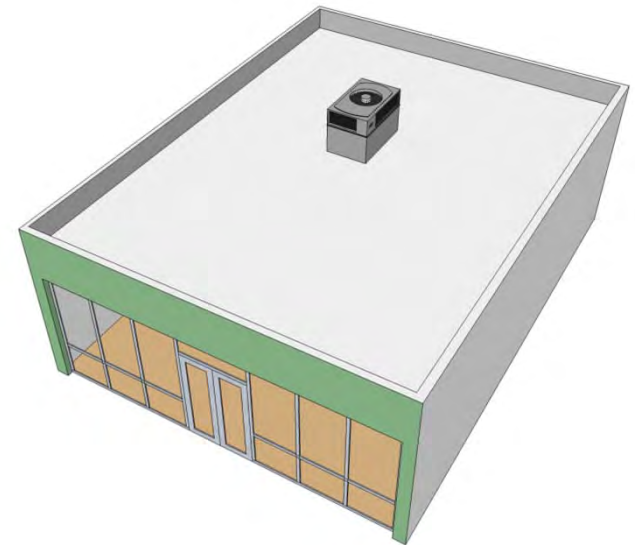
R-30 insulation

or

Cool roof membrane



(R-38 for group R buildings)



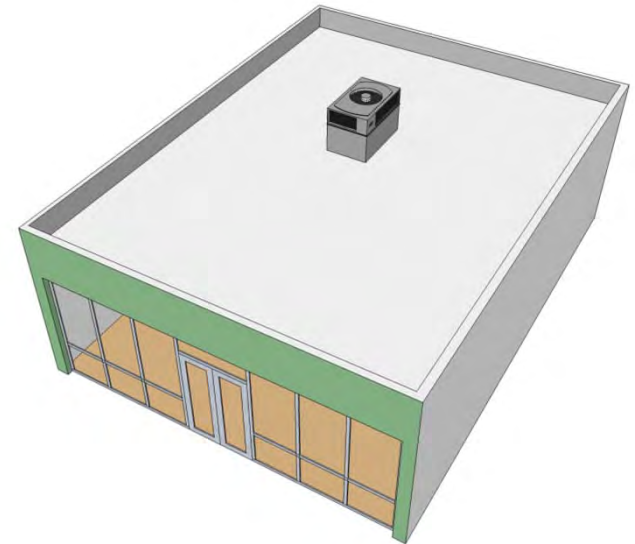
ROOF INSULATION ABOVE DECK

R-value
compliance
option
(502.2)

R-15 insulation

or

Cool roof membrane



(R-20 for group R buildings)

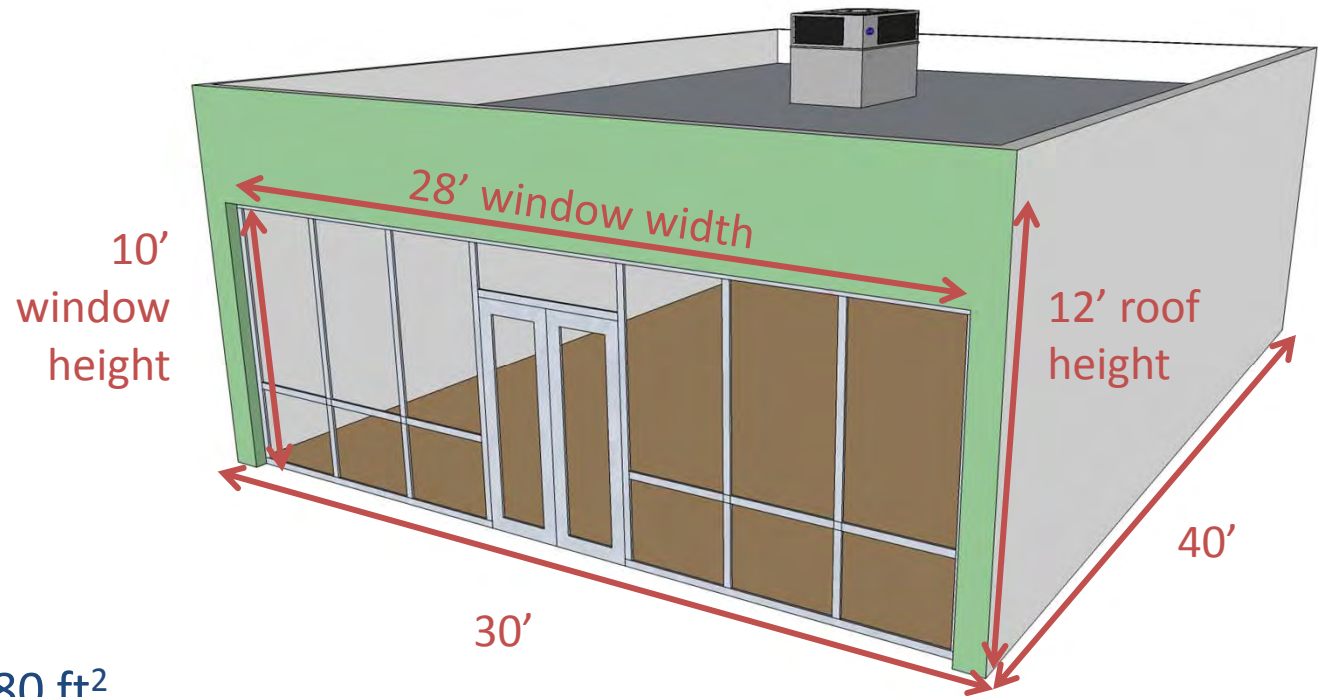
- Typical R-15 options:
- 3 in. polystyrene
 - 2.5 in. polyisocyanurate

COMMERCIAL
Envelope

WINDOW AREA LIMIT

(502.3.1)

Is window area \leq 40% gross wall area?



Window area = 280 ft²

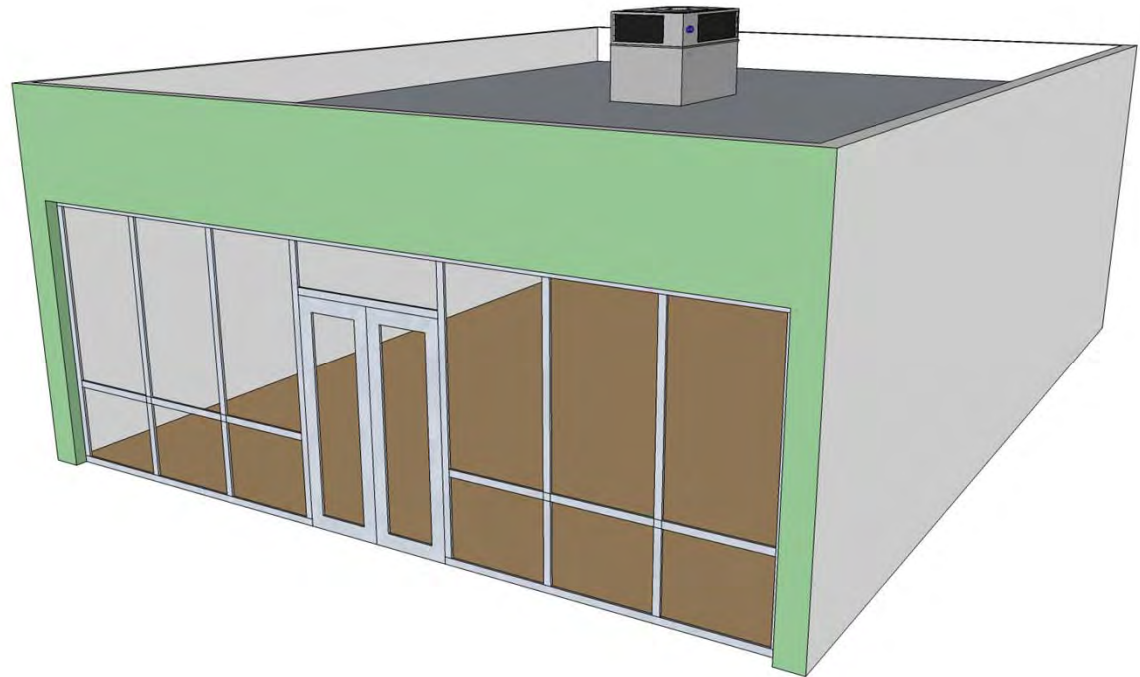
Gross wall area = (30 + 40 + 30 + 40) * 12 = 1,680 ft²

% Window area = 280 / 1,680 = 17% OK

**WINDOW
MAXIMUM
SHGC**

(502.3.2)

What is maximum allowed SHGC?



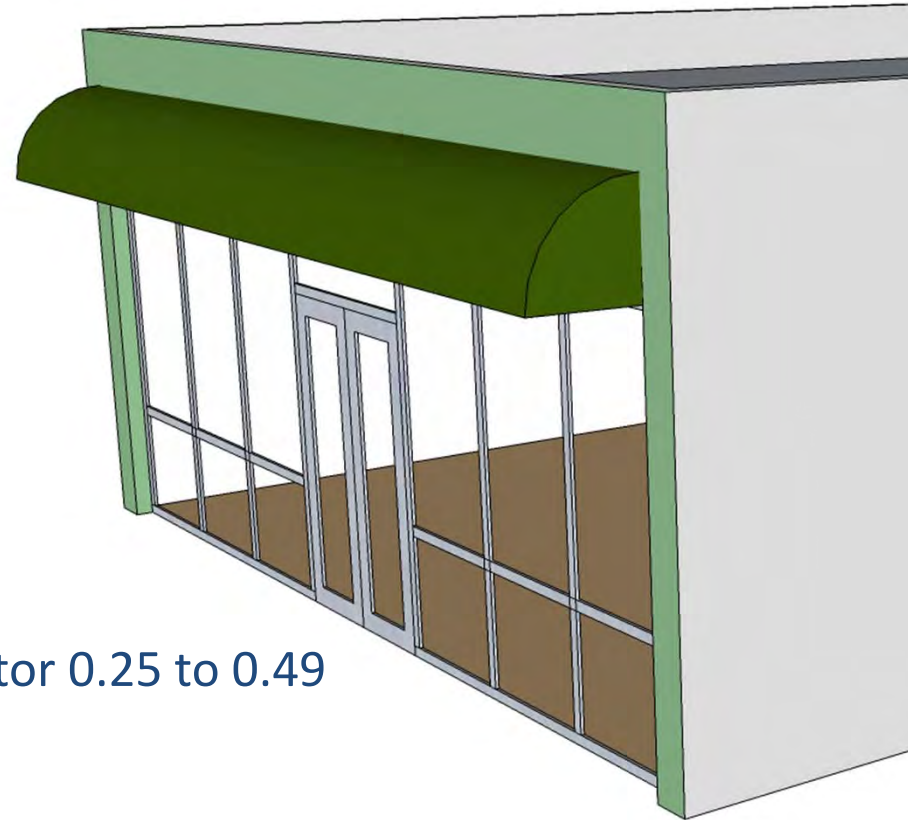
No overhang shading

Maximum SHGC = 0.25

**WINDOW
MAXIMUM
SHGC**

(502.3.2)

What is maximum allowed SHGC?



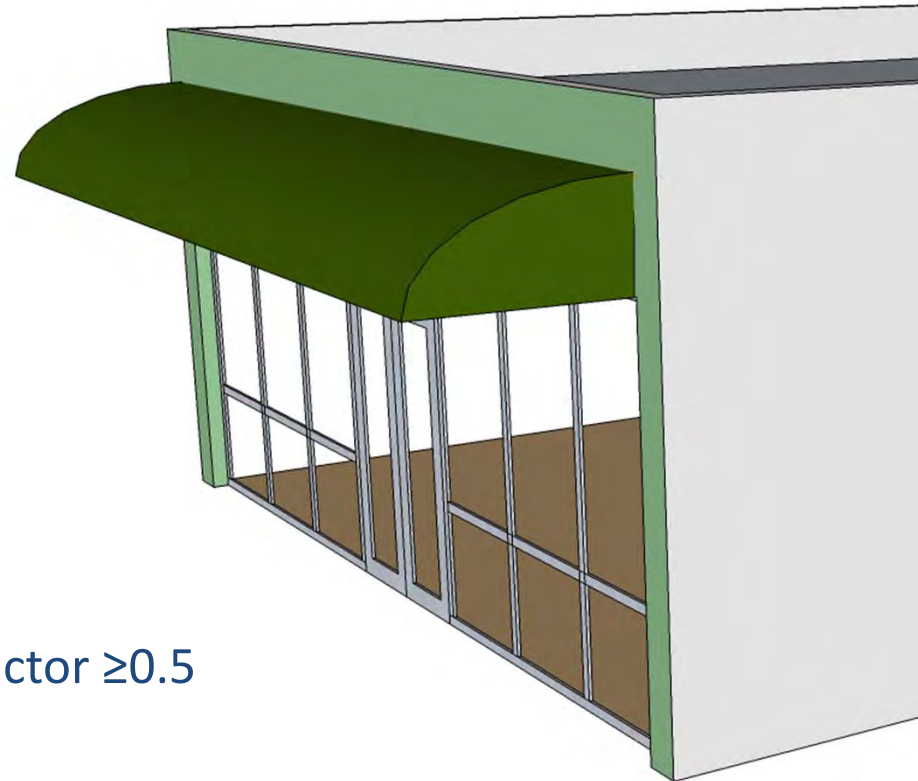
Overhang projection factor 0.25 to 0.49
(2.5' to 4.9' in this case)

Maximum SHGC = 0.33

**WINDOW
MAXIMUM
SHGC**

(502.3.2)

What is maximum allowed SHGC?



Overhang projection factor ≥ 0.5
($\geq 5'$ in this case)

Maximum SGHC = 0.40

Example Commercial Glazing Products

Name	Glass Type	Coating	U-factor (center of glass)	SHGC	VLT	VLT/ SHGC ratio
Clear	¼" clear	None	1.02	0.82	0.88	1.1
Double Clear	¼" clear / ¼" clear	None	0.47	0.70	0.79	1.1
VE1-85	¼" clear / ¼" clear	Low-e	0.31	0.54	0.76	1.4
VE1-55	¼" clear / ¼" clear	Low-e	0.31	0.35	0.47	1.3
VE2-55	¼" green / ¼" clear	Low-e	0.31	0.26	0.40	1.5
VE4-55	¼" gray / ¼" clear	Low-e	0.31	0.25	0.27	1.1

The background of the slide is a photograph of trees, likely a forest or park, with a semi-transparent green overlay. The trees are dense and their branches are visible against a lighter sky. The overall tone is natural and serene.

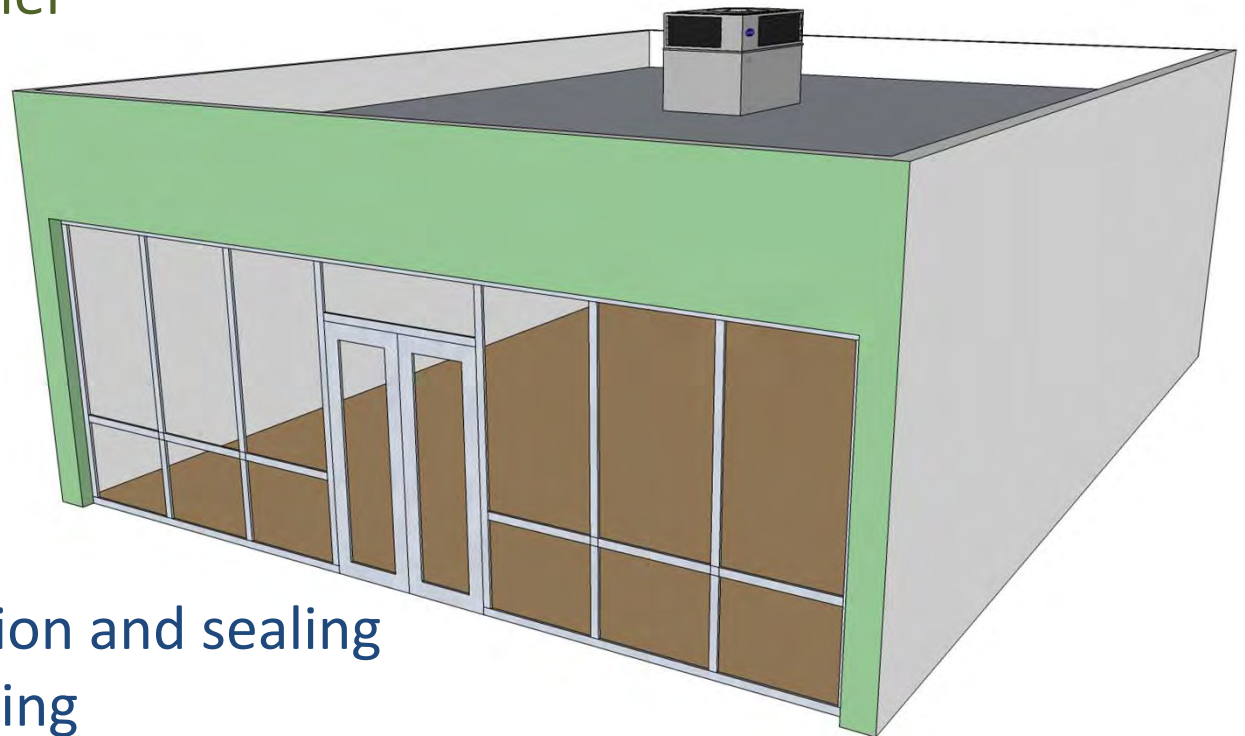
2009 IECC

SMALL COMMERCIAL MECHANICAL

HVAC

COMMERCIAL
Mechanical

Packaged single-zone
rooftop air conditioner
is common



503.2.3 Efficiency
503.2.5 Ventilation
503.2.7 Duct insulation and sealing
503.2.9 Commissioning
502.2.10 Air system (fan power)

503.2.3 Efficiency

See Table 503.2.3

Depends on equipment type & size

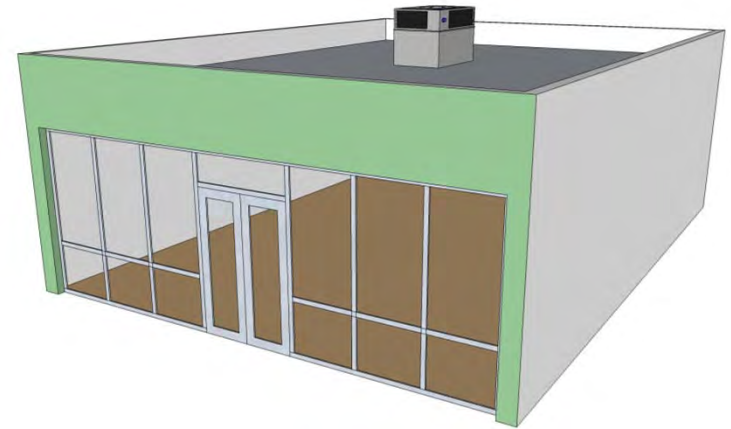
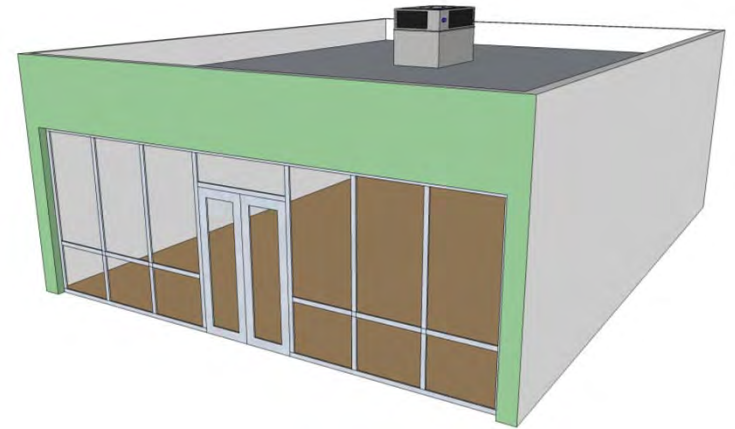


TABLE 503.2.3(1)
UNITARY AIR CONDITIONERS AND CONDENSING UNITS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY ^b	TEST PROCEDURE ^a
Air conditioners, Air cooled	< 65,000 Btu/h ^d	Split system	13.0 SEER	AHRI 210/240
		Single package	13.0 SEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Split system and single package	10.3 EER ^c (before Jan 1, 2010) 11.2 EER ^c (as of Jan 1, 2010)	

503.2.5 Ventilation



- Outdoor air ventilation per International Mechanical Code
- Equal to ASHRAE Standard 62.1
 - For example:
 - **$0.06 \text{ cfm/ft}^2 + 5 \text{ cfm/person}$ for office space**

HVAC

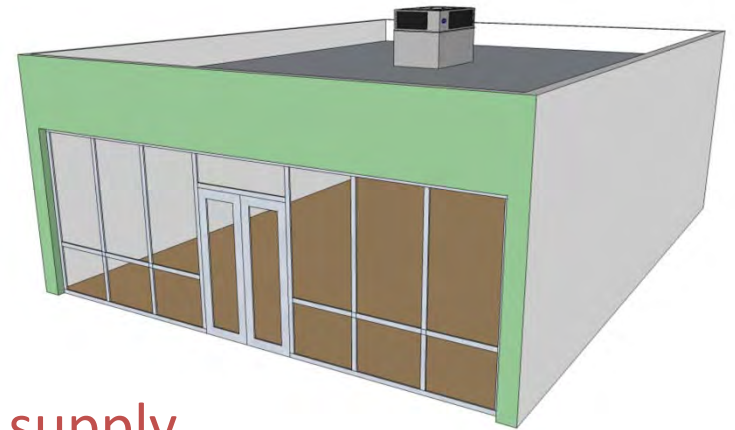
COMMERCIAL
Mechanical

503.2.7 Duct and plenum insulation and sealing

Minimum insulation:

R-8 for ducts outdoors

R-5 for ducts in unconditioned space



For both supply
and return ducts



Source: www.energycodes.gov

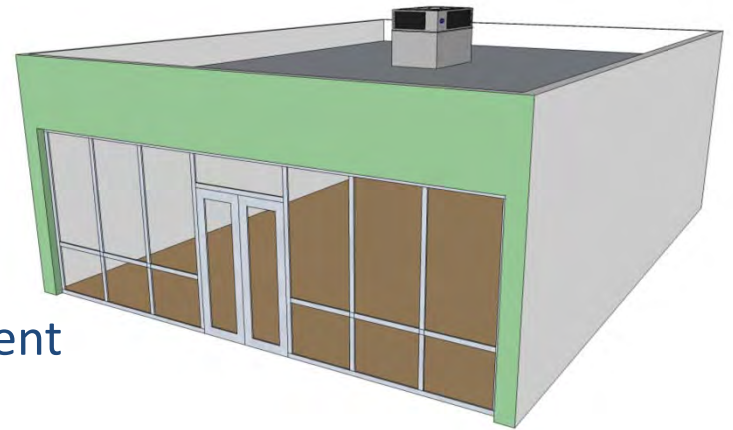
503.2.9 Commissioning and Completion

System commissioning

- Drawing notes require commissioning
- Details can be in specs

Written statement

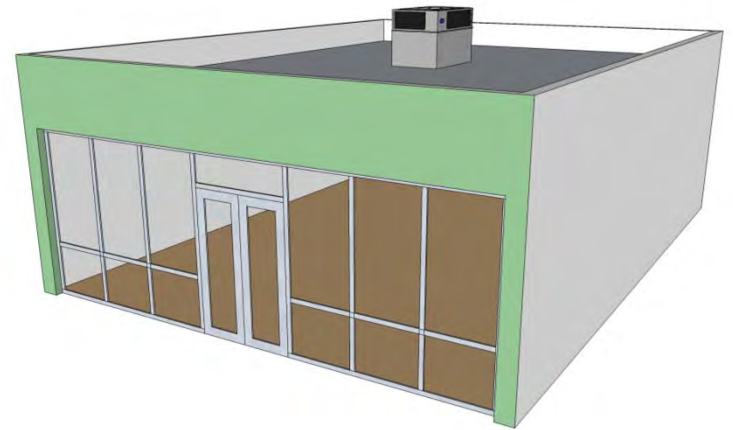
- Design professional provides written statement
- Prior to certificate of occupancy



503.2.9 Commissioning and Completion (continued)

Commissioning plan contents

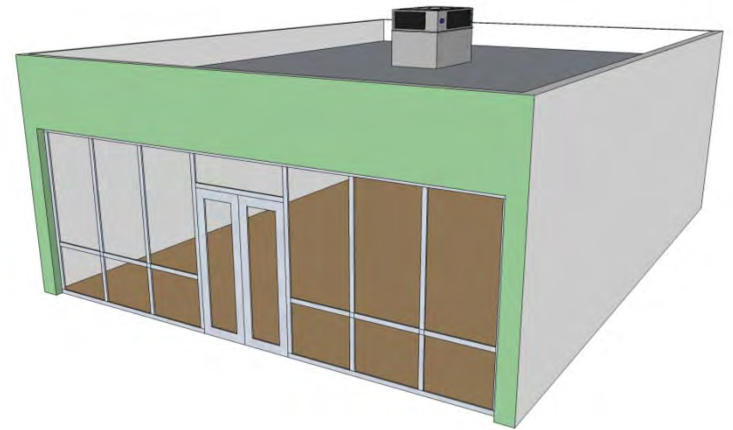
- Owner's project requirements
- Narrative of activities at each project phase
- Systems to be tested
- Functions to be tested
- Conditions for testing
- Acceptance criteria



503.2.9 Commissioning and Completion (continued)

Systems adjusting and balancing

- Air flow +/- 10% of design rate
- Adjust fan speed (not discharge dampers)



Sample commissioning documents

Commissioning Toolkit for Small Buildings

<http://www.green.ca.gov/GreenBuildings/CxToolKit.aspx>

Commissioning Plan

DGS Commissioning Plan for Small Buildings¹ TEMPLATE – January 29, 2007²

(Revisions indicated compared to September 13, 2006 version)

1. General Project Information

Project Name	
Project Address	
Building Type	
Building Size (ft ²)	
Building Description	
Owner/Agency	
Scheduled Completion Date	
Project Director	
Commissioning Authority	
ABMS Number	

2. Commissioning Goals

- Perform commissioning tasks consistent with LEED-NC 2.2 Energy and Atmosphere Prereq.1
- Other:

3. Systems to be Commissioned

System Type ³	Check if Applicable
HVAC	
Packaged units (AC and HP)	
Ductwork	
Boiler	
Heating hot water pumps	
Terminal units (air)	
Unit heaters	
HVAC control system	
Fire and smoke dampers	
Other:	
ELECTRICAL	
Lighting occupancy sensors	
Lighting timer controls	
Lighting photocell controls	

Owner's Project Requirements

DGS Owner's Project Requirements for Small Buildings¹ DRAFT TEMPLATE – August 19, 2006²

[Note to Project Director: Documentation of Owner's Project Requirements (OPR) is a step required for compliance with LEED-NC 2.2 EA Prerequisite 1 for Fundamental Commissioning of the Building Energy Systems. This template is a guide to collecting the information recommended in the LEED-NC Version 2.2 Reference Guide. The information should be developed by the project team in collaboration with the client agency (Owner).]

1. Owner and User Requirements

- A. *[Typically already covered in Project Scope as described in Budget Package. Includes primary purpose, program and use of project. May also describe future expansion needs, flexibility, quality of materials, construction and operation costs.]*

2. Environmental and Sustainability Goals

- A. Project shall meet LEED-NC 2.2 requirements at the Silver performance level.
B. Other Owner requirements: *[e.g. Owner priorities among possible LEED points]*

3. Energy Efficiency Goals

- A. Project shall comply with Title 24 building energy efficiency standards.
B. Lighting systems offer cost effective energy savings potential, and lighting fixtures and/or controls shall be selected to exceed Title 24 minimum efficiency requirements by 10% or greater.
C. High efficiency HVAC equipment offers cost effective energy savings, and HVAC equipment shall be selected that exceeds Title 24 minimum efficiency requirements by 10% or greater.
D. Additional energy efficiency measures that provide cost effective energy savings shall be included wherever feasible.
E. Other Owner requirements: *[e.g. orientation, siting, daylighting, cool roof, natural ventilation, landscaping]*

4. Indoor Environmental Quality Requirements

- A. Indoor lighting requirements: *[List any specific non-standard requirements. E.g. pendant-mounted lighting, illumination requirements, special applications.]*
B. Occupant lighting control requirements: *[List any non-standard requirements. E.g. multi-mode controls for assembly spaces]*
C. Thermal comfort requirements: *[List any non-standard temperature or humidity requirements]*
D. Ventilation and filtration requirements: *[List any non-standard requirements]*
E. Occupancy HVAC control requirements: *[List any non-standard requirements. E.g. integration with existing control systems]*

Sample
commissioning
documents
(continued)

Functional
performance
test form

Project Name:		
Equipment Tag:		
Test Date/Time:		
Participants:	Name	Organization
Comments:		

Operating Schedule - Record time-of-day and setpoints and note any deviation from DESIGN

	DAY OF THE WEEK							Override available?
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	
Design:	7AM-6PM	7AM-6PM	7AM-6PM	7AM-6PM	7AM-6PM	override	override	Yes
Actual:								
Comments:								

Prefunctional Checklist

Record values for current setpoints, control parameters, limits, delays, lockouts, etc. and note any deviation from design.

Parameter	Per Design	Observed
Power to unit		
Power disconnects installed and labeled.		
Thermostat is wired to the HVAC system correctly		
Thermostat meets deadband control requirements		
Space temperature sensor calibrated		
Occupied, unoccupied, and holiday schedules programmed		
Pre-occupancy purge has been programmed		
Set up and set back setpoints programmed as required		
Thermostat located within the zone that the HVAC unit serves		
Unoccupied avg. zone set points (e.g. 85°Fsetup/60°Fsetback)		
Schedule override		
Condensate drain connected		
CO2 sensor location		
CO2 sensor calibrated		
Return air damper moves through full range		
Outdoor air damper moves through full range		
No excessive damper linkage slop.		
Permanent label attached.		
Unit secure and level.		
Maintenance access ok.		
Test, adjust and balance complete with deficiencies corrected.		
Outdoor air economizer switchover type and setting		
Casing condition ok.		

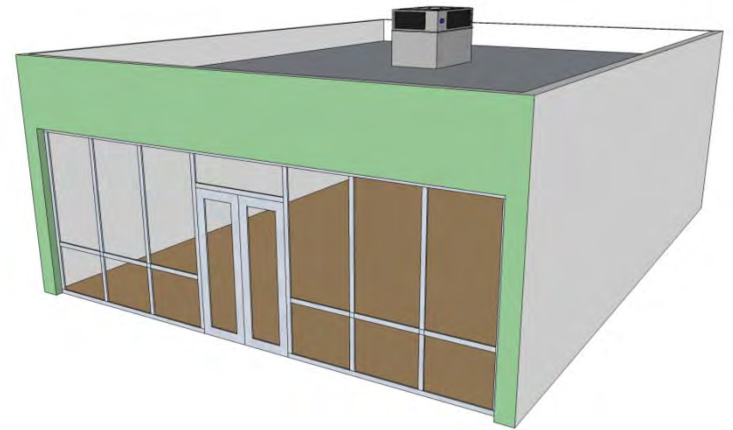
HVAC

COMMERCIAL
Mechanical

502.2.10.1 Allowable fan power horsepower

Applies if total fan motor horsepower $> 5\text{hp}$

Typically if ≥ 10 ton cooling capacity



HVAC

COMMERCIAL
Mechanical

Summary

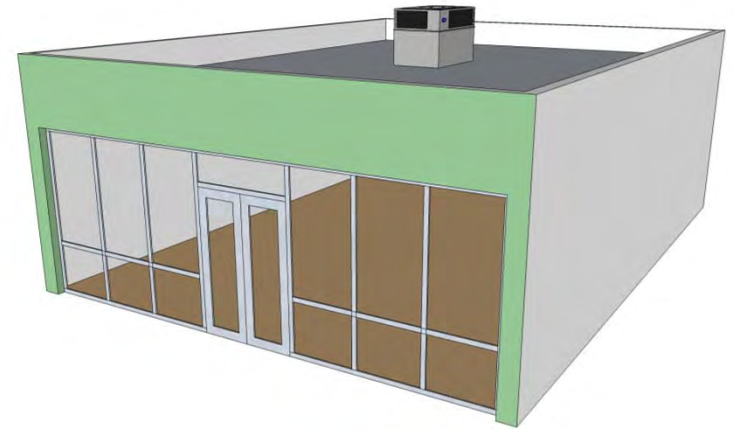
503.2.3 Efficiency

503.2.5 Ventilation

503.2.7 Duct insulation and sealing

503.2.9 Commissioning

502.2.10 Air system (fan power)



ID	Supply Airflow	Outdoor Airflow	Fan Power	Cooling Capacity	Efficiency
AC-1	1,200 cfm	120 cfm	1 hp	36,000 Btu/hr	13 SEER

- ➔ + Duct insulation on plan and/or specs
- ➔ + Commissioning requirement noted on plans

HVAC

Beyond Code...

- Variable air volume control (vs. constant volume)
- “Right sizing”
- Dual path air handler
- Demand controlled ventilation



2009 IECC

SMALL COMMERCIAL INTERIOR LIGHTING

Interior Lighting

COMMERCIAL Lighting

- What is allowed interior lighting power?
 - Floor area is 1,200 ft²
 - Office occupancy

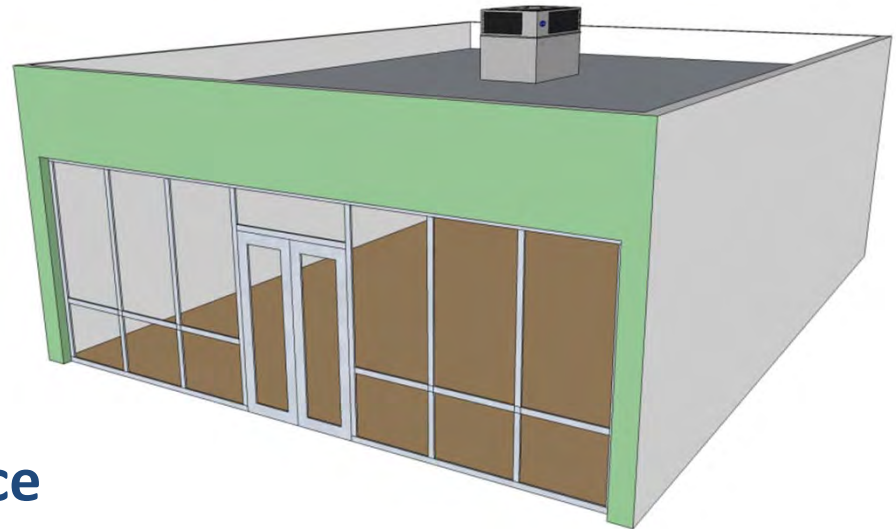


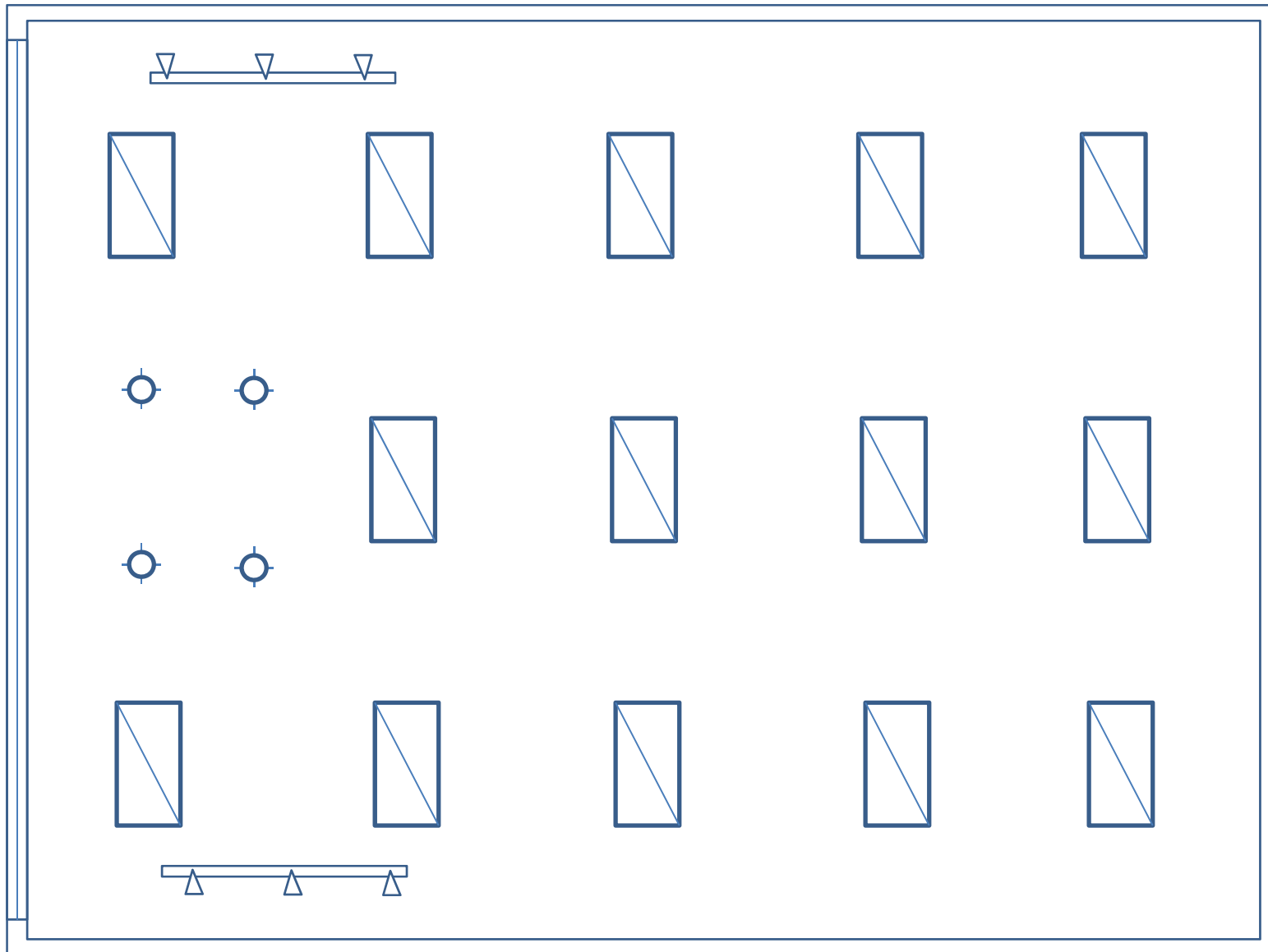
Table 505.5.2 Allowance

Office = 1.0 W/ft²


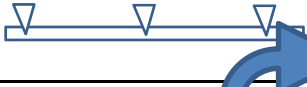

$$1.0 \text{ W/ft}^2 \times 1,200 \text{ ft}^2 = 1,200 \text{ watts allowed}$$

LIGHTING PLAN

What is the installed lighting power?



LIGHTING SCHEDULE What is the installed lighting power?




Symbol	Description	Input Power	Qty	Total Power
	2, 4-ft T-8 lamps, high efficiency electronic ballast, 120V	55W	14	770W
	8-ft track, three 20W halogen lamps, 120V	60W	2	120W
	CFL downlight, 120V	26W	4	104W
			Total	994W

Vs. 1,200 watts allowed

Complies?

505.5.1.4 says, line voltage track lighting power counts for at least 30 W/ft

LIGHTING SCHEDULE What is the installed lighting power?

Symbol	Description	Input Power	Qty	Total Power
	2, 4-ft T-8 lamps, high efficiency electronic ballast, 120V	55W	14	770W
	8-ft track, three 20W halogen lamps, 120V	60W 240W	2	120W 480W
	CFL downlight, 120V	26W	4	104W
			Total	994W 1354W

Vs. 1,200 watts allowed

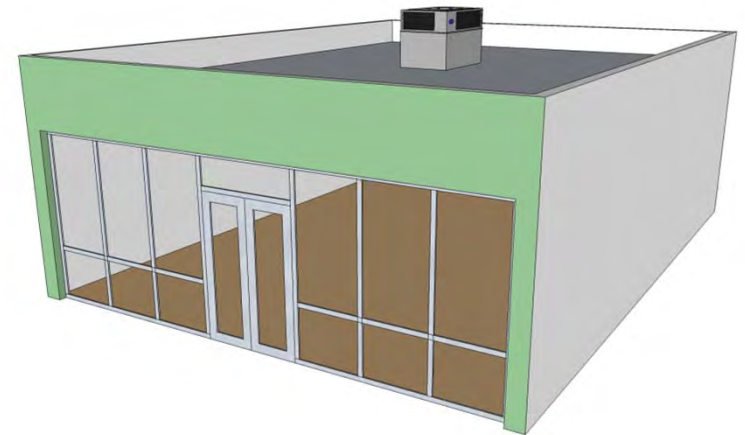
Does not comply

505.5.1.4 says, line voltage track lighting power counts for at least 30 W/ft

Interior Lighting

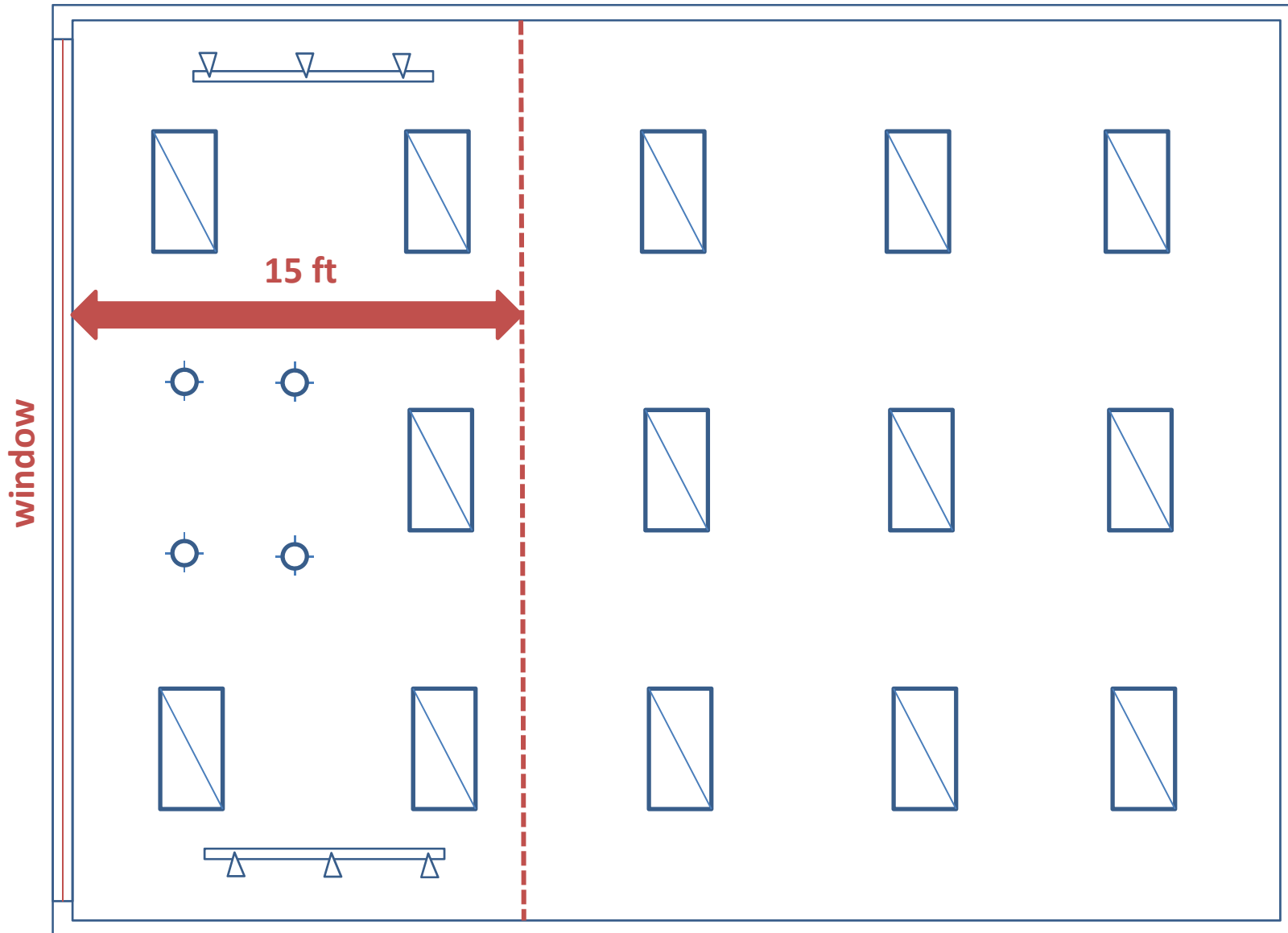
COMMERCIAL Lighting

- What are the lighting control requirements?
 - 505.2.1 Manual control
 - 505.2.2.1 Light reduction
 - 505.2.2.3 Daylight zone control



DAYLIGHT ZONE CONTROL

Separate switch for fixtures in daylight zone



Beyond Code... Lighting Design Strategies

COMMERCIAL
Lighting

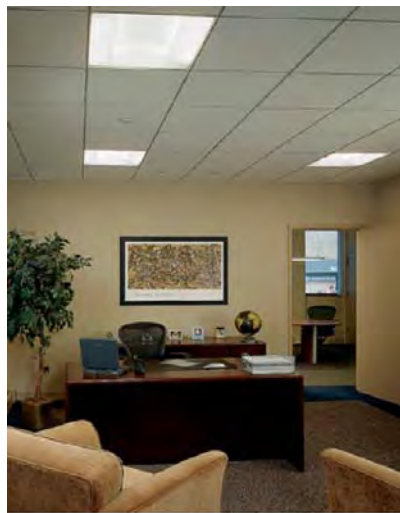
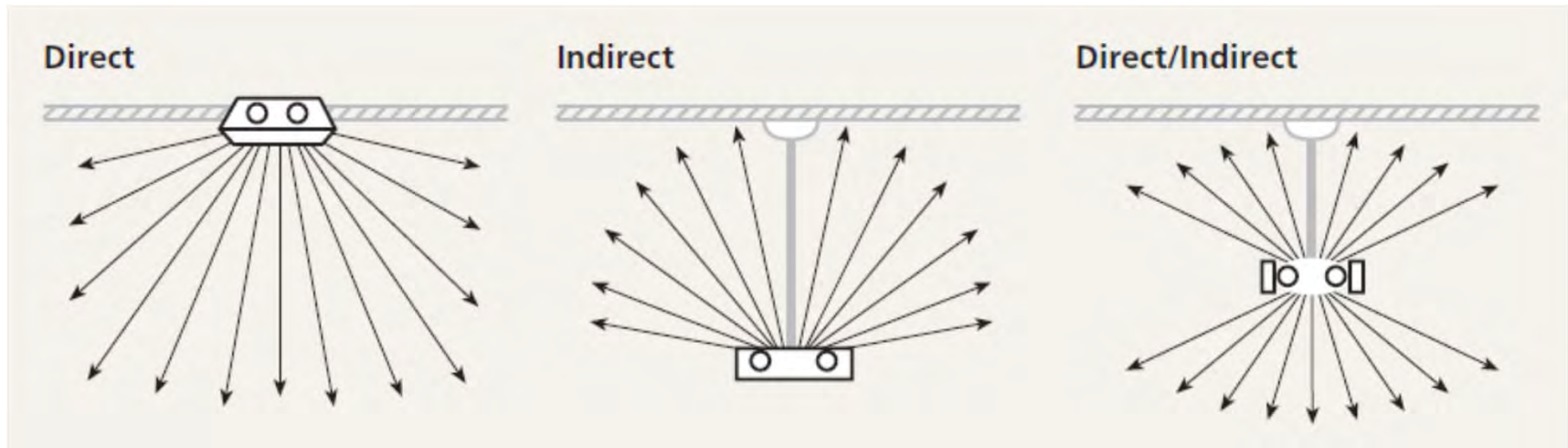


Photo Courtesy of Focal Point Lighting

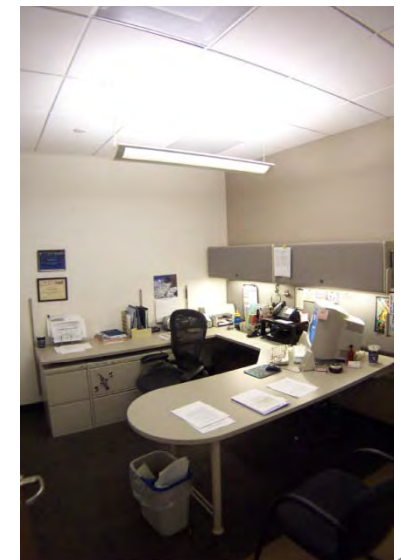


Photo Courtesy Benya Lighting Design

Beyond Code... Lighting Design Strategies

COMMERCIAL Lighting

Direct

- “Down light”
- Efficient for horizontal (e.g. desktop) illumination
- Relatively dark ceiling
 - “Cave like”
- Potential for glare from bright fixture
- Harsher shadows
- But more “dramatic”

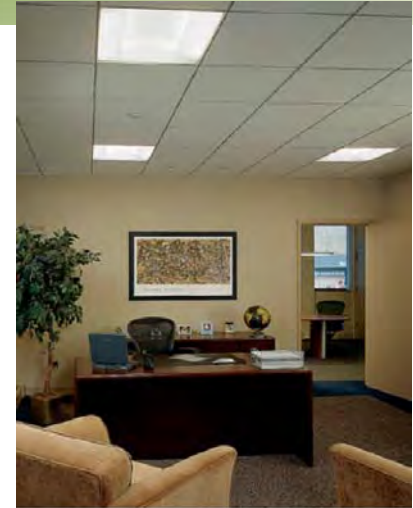


Photo Courtesy of Focal Point Lighting



Photo Courtesy of Focal Point Lighting

Beyond Code... Lighting Design Strategies

COMMERCIAL
Lighting

- Indirect
 - “Up light”
 - Bright ceiling
 - Even light
 - Diffuse light
 - Softer shadows
 - May require higher ceiling
 - 12-18 in. clearance for suspended fixtures (typical)
 - Good with computer displays
 - Space may feel more “open”
 - Need reflective ceiling



Photo Courtesy of Benya Lighting Design

Beyond Code... Lighting Design Strategies

COMMERCIAL
Lighting

- Direct/indirect
 - Avoids dark ceiling
 - More efficient horizontal illumination than “indirect” alone



Photo Courtesy Benya Lighting Design

The background of the slide is a photograph of trees, likely a large tree with thick branches, overlaid with a semi-transparent green filter. The text is positioned in the lower-left quadrant of the image.

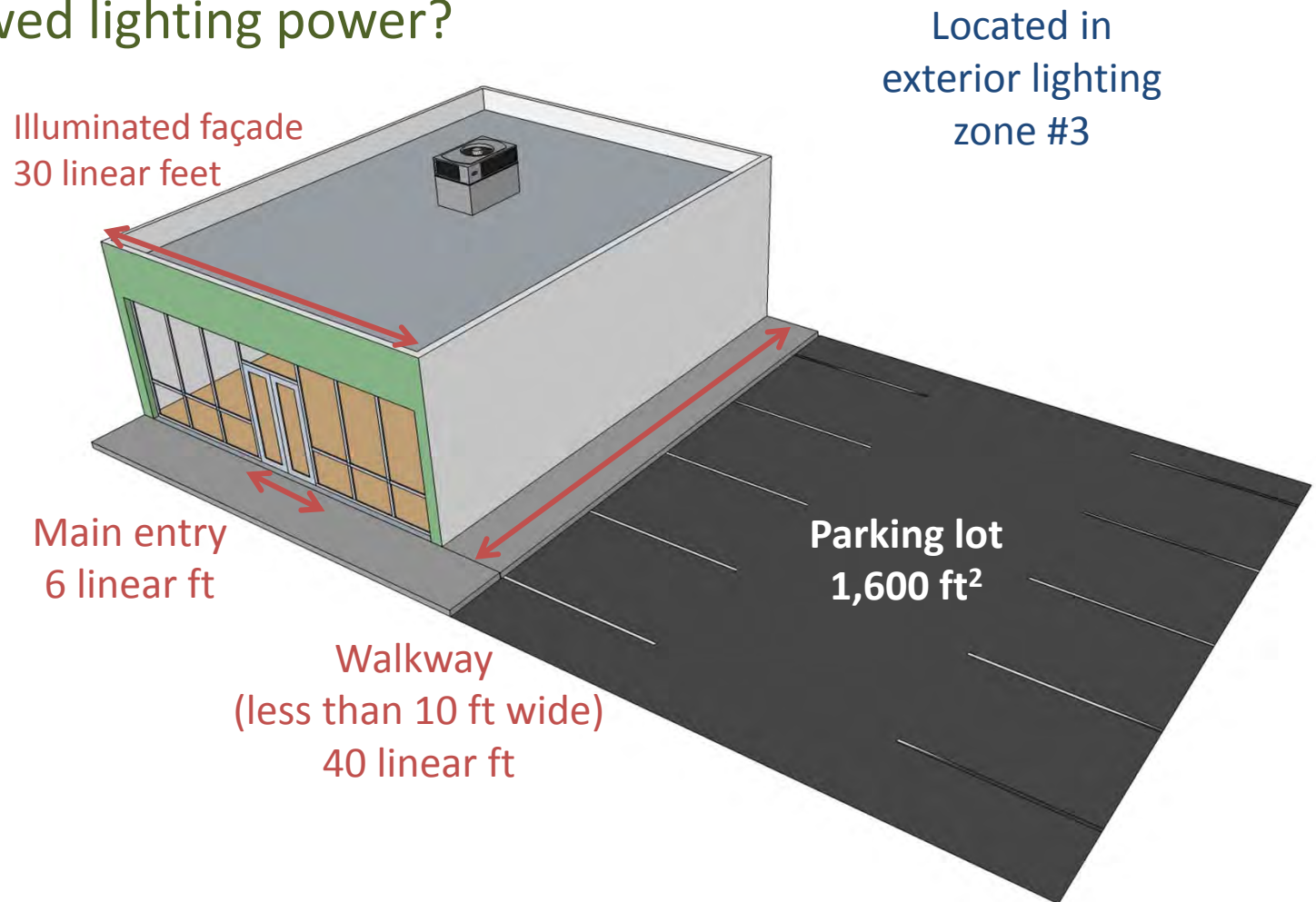
2009 IECC

SMALL COMMERCIAL EXTERIOR LIGHTING

Exterior Lighting Power

COMMERCIAL
Lighting

What is allowed lighting power?



Exterior Lighting Power Allowances

COMMERCIAL
Lighting

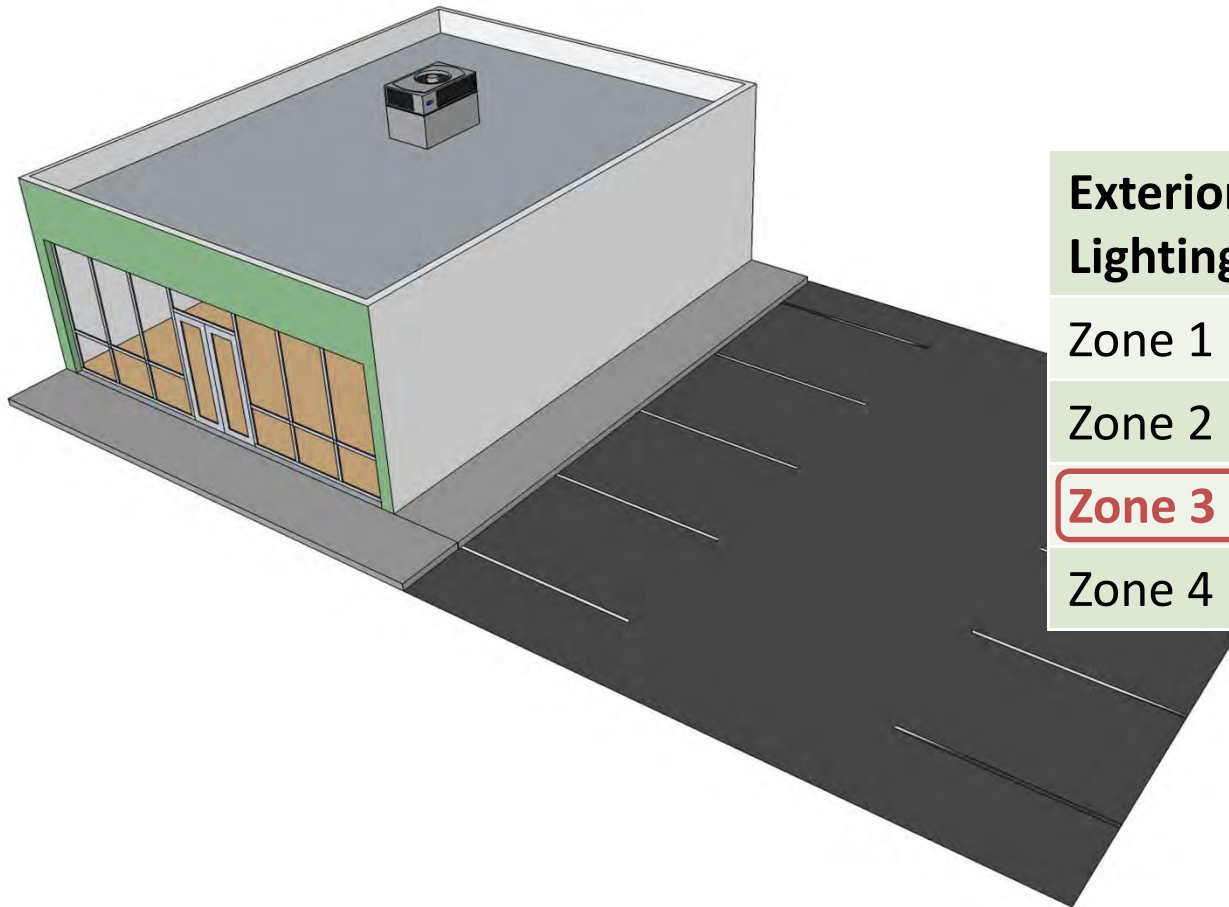
505.6.2

1. Base site allowance
2. Tradable surfaces
 - Sum allowance for all surfaces
3. Nontradable surfaces
 - Each surface comply separately

Exterior Lighting Power

COMMERCIAL
Lighting

1. Base site allowance



Located in
exterior lighting
zone #3

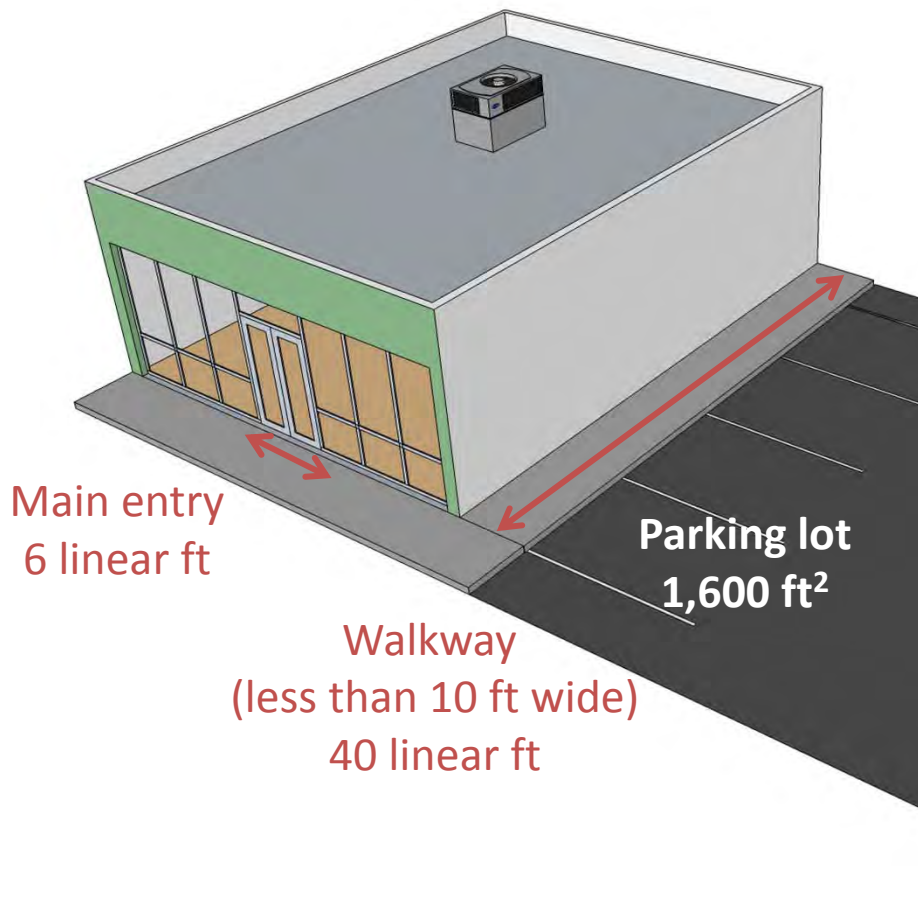
Exterior Lighting Zone	Base Site Allowance
Zone 1	500 W
Zone 2	600 W
Zone 3	750 W
Zone 4	1300 W

Exterior Lighting Power

COMMERCIAL
Lighting

2. Tradable surfaces

Located in
exterior lighting
zone #3



Surface	Area/ length	Unit Allowance	Allowance
Parking lot	1,600 ft ²	0.10 W/ft ²	160W
Walkway	40 ft	0.80 W/ft	60W
Main entry	6 ft	30 W/ft	180W
Subtotal			400 W
Base site allowance (previous slide)			750 W
Total			1,150 W

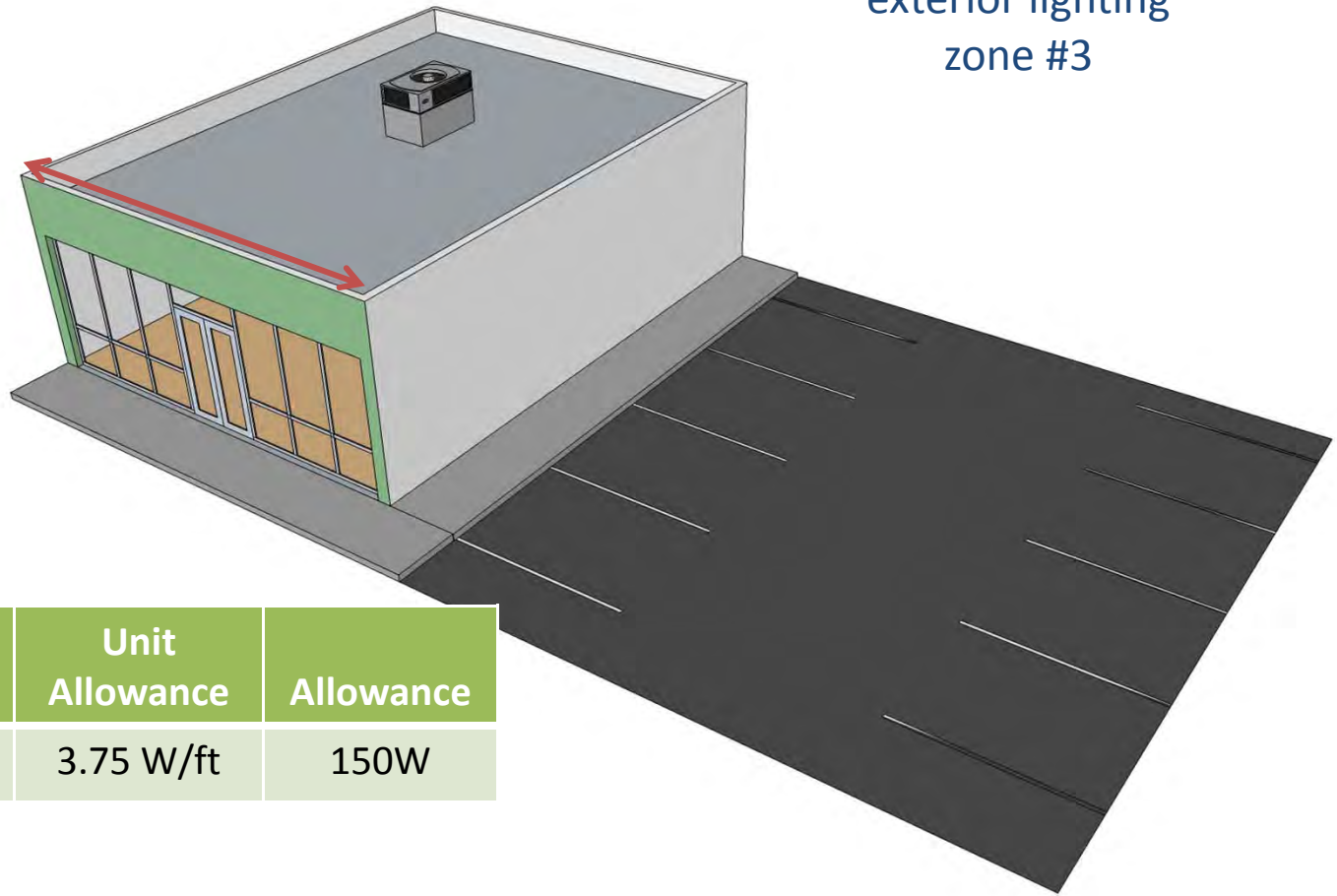
Exterior Lighting Power

COMMERCIAL
Lighting

3. Non-tradable surfaces

Located in
exterior lighting
zone #3

Illuminated façade
30 linear feet



Surface	Area/ length	Unit Allowance	Allowance
Facade	30 ft	3.75 W/ft	150W

Exterior Lighting Example LED Fixtures

COMMERCIAL
Lighting



Source: DOE/NREL PIX16664



2009 IECC

WRAP UP

Questions?

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