METAL BUILDING
CONTRACTORS & ERECTORS ASSOCIATION

Daylighting Layout via Skylights

RCS

Presentation Overview

Bring Daylight Design Full-Circle: Considerations for Incorporating Skylights in Pre-Engineered Metal Buildings

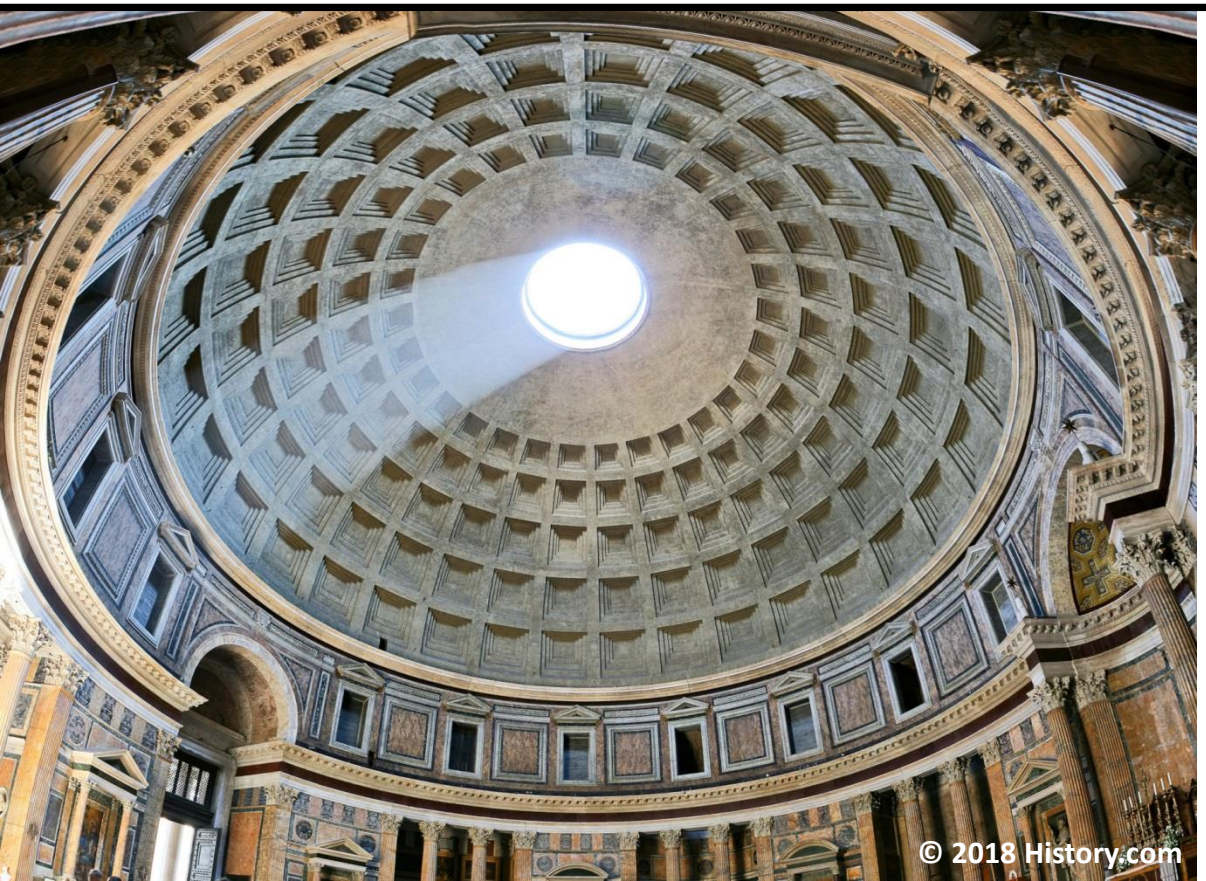
- **Skylight Characteristics**
- **Effective Daylighting Layout**
- **Potential Energy Savings**
- **Importance of Life Safety**

RCS

Presentation Objective

Provide relevant information pertaining to the use of high-performance skylights that gives you a competitive advantage for upcoming energy driven code initiatives and instances where your customer requires daylighting in their building.

What <u>renewable energy source</u> has been incorporated into buildings for centuries as an evolving technology focus for improving building efficiency?




Natural lighting from the Sun!

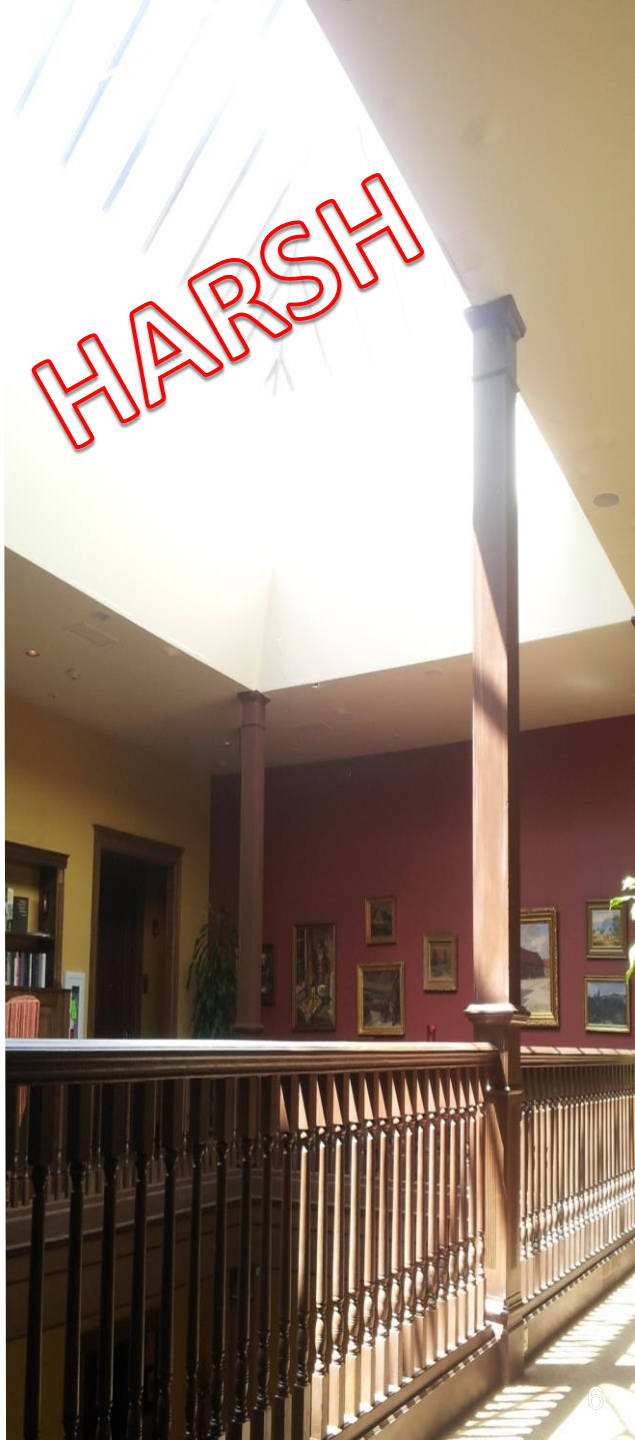
Daylighting

Vs.

Sunlighting

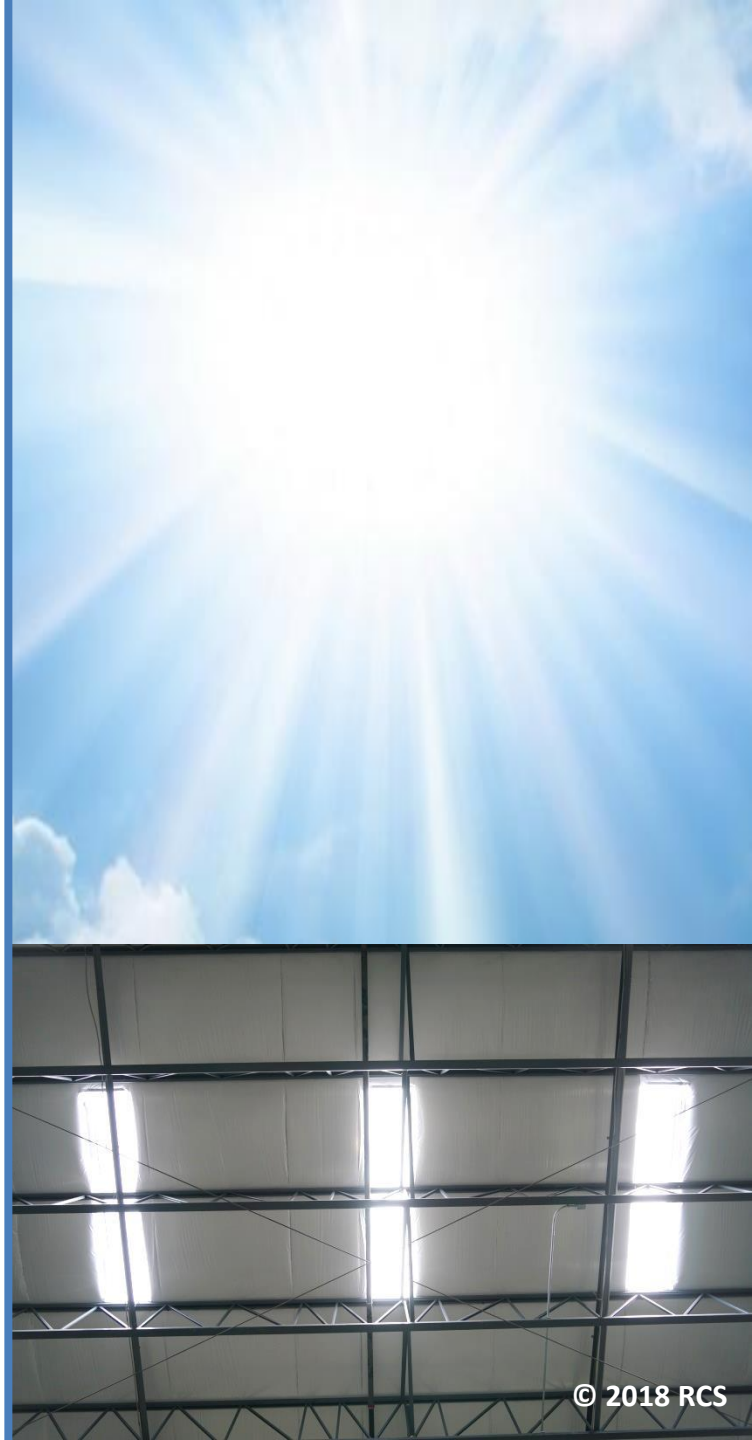
Daylight is the intentional and controlled introduction of natural light into a space to be used as the main illumination source.

The most common form of Daylighting in buildings is via side-lighting through windows, however we are going to focus on top-lighting large spaces where only skylights can properly illuminate the floor.



Daylight Matters

- The Sun delivers 10,000 foot candles of 100% CRI (Color Rendering Index) light on a clear day - for free! The light yield from the Sun is between 2,000 and 7,000 foot candles even on a cloudy day.
- The human eye was designed to interpret natural light which is the basis for all electric lighting measurements.
- Properly diffused daylight is still the highest lumen per watt light source available on the Earth. ZERO ELECTRIC ENERGY TO PRODUCE AND SUBSTANTIALLY LESS HEAT!



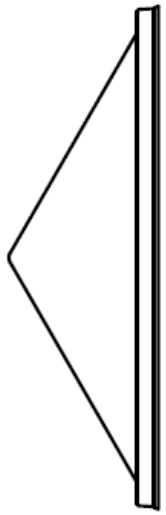
Top-Down Look at Daylighting

- To a varying degree, skylights are effective all day at illuminating interior spaces which can be amplified through the use of reflective wells and elevated shapes.
- The thermal performance of a skylight is characterized by construction techniques and materials that are configurable based on the geographic location and building usage.
- Diffusion, most commonly achieved through specially designed lenses, maximizes light transmission and optimizes performance through uniform distribution of natural light.

Common Skylight Dome Shapes Incorporated into the Design of Metal Buildings

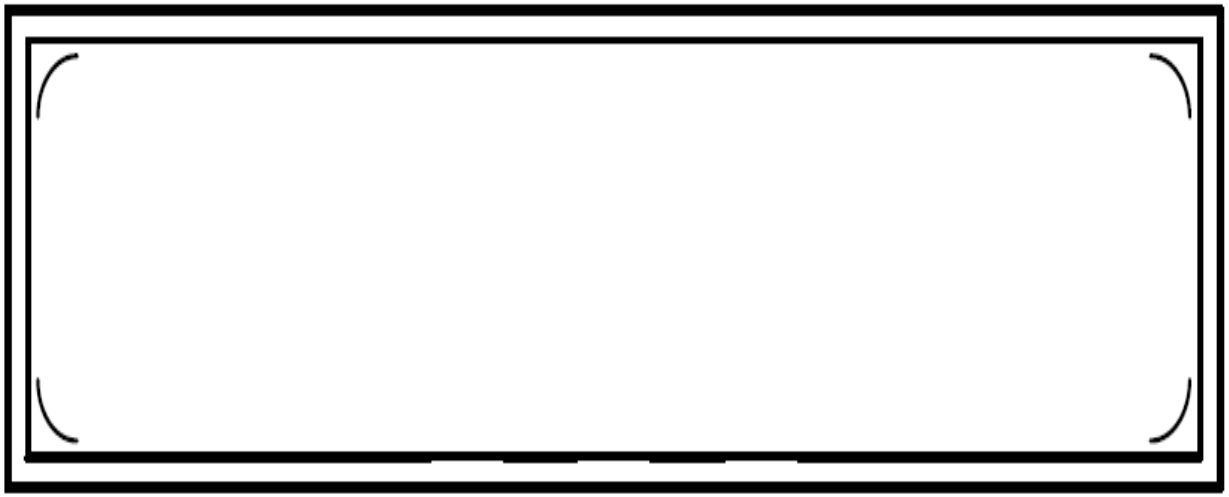
Common Skylight Shapes

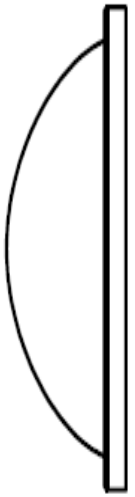
Pyramid



Common Skylight Shapes

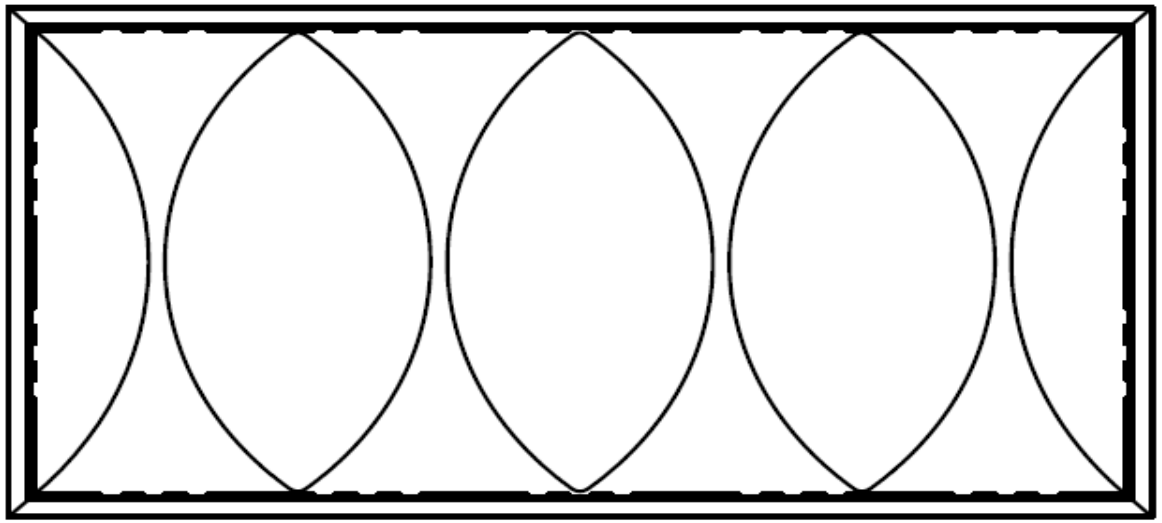
Dome

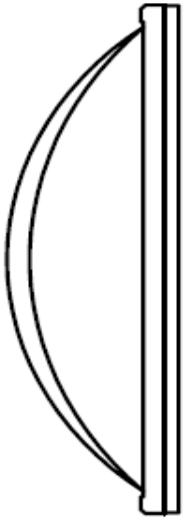




Common Skylight Shapes

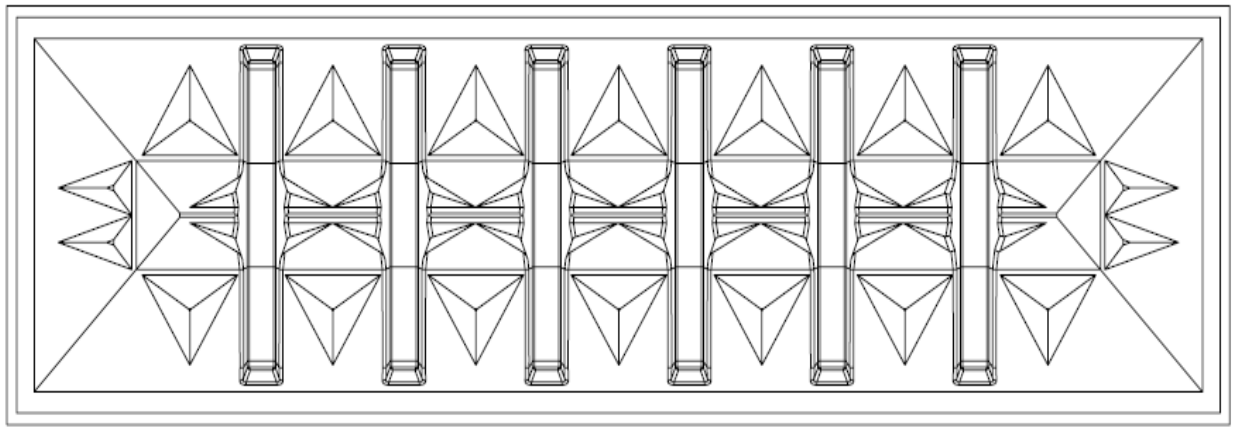
Triarch

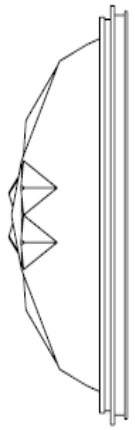


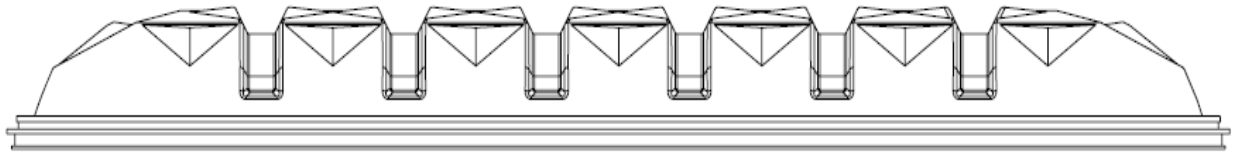


Common Skylight Shapes

Dynamic Dome







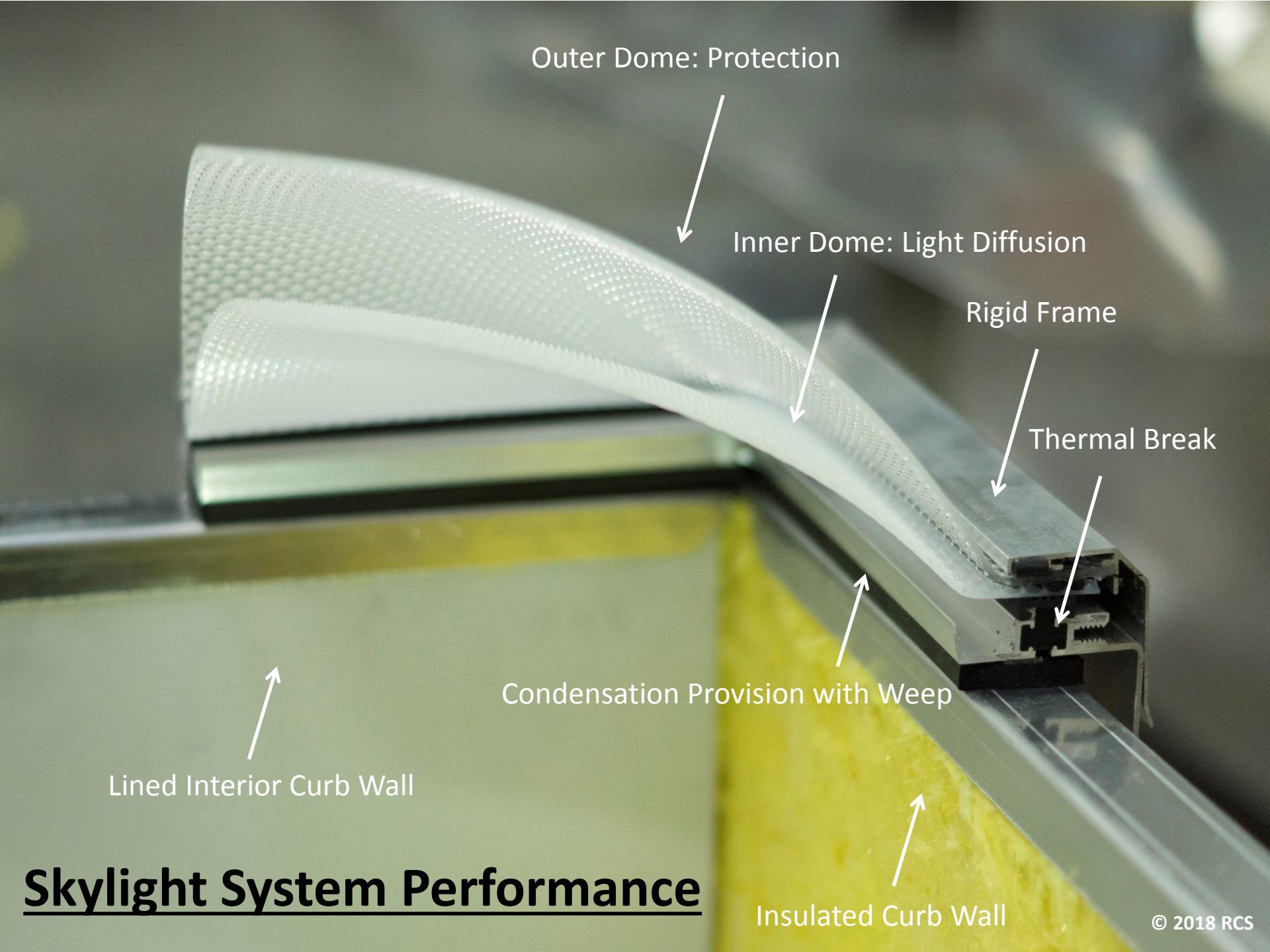
Acrylic Glazing

Acrylics are well suited for skylight glazing due to their clarity, impact resistance, durability, weather resistance, low weight to strength ratio and formability A .125" thick general-purpose acrylic sheet is approximately 2 to 3 times more impact resistant than double strength window glass, and about 4 to 5 times more impact resistant than wire glass or other glasses. A .250" general-purpose acrylic sheet is approximately 9 to 10 times more impact resistant than wire glass or other glasses.

The most common glazing combination for industrial/commercial double glazed skylights is clear over white. This glazing combination formed with the appropriate acrylic thickness and an effective dome shape is very cost efficient in providing a good balance between light transmission (LT), haze/diffusion, solar heat gain (SHGC) and insulating properties (U Factor). Acrylics are CC2 fire rated and their typical service life is approximately ten years.

Polycarbonate Glazing

Polycarbonates are widely used plastics from a specific group of thermoplastic polymers with one of the key characteristics is that they have extremely strong molecular bonds which make polycarbonates tough and durable. Polycarbonates have high impact resistance, clarity, fire resistance and with UV coatings are extremely versatile in their application. Polycarbonates are well suited to LEED projects as they are 100% recyclable material and most manufacturers use up to 25% recycled material in the manufacture of polycarbonates. Low U-Factors and highly diffused light transmission make polycarbonates a good daylighting material. Polycarbonate is CC1 fire rated and its typical useful service life is approximately fifteen years.



Skylight System Performance

Relevant Performance Terms

U-Factor (U-Value)

A measure of the heat gain or loss through glazing due to the difference between indoor and outdoor air temperatures. It is also referred to as the overall coefficient of heat transfer. A lower U-factor indicates better insulating properties. The units are Btu/(hr)(ft2)(°F).

Solar Heat Gain Coefficient (SHGC)

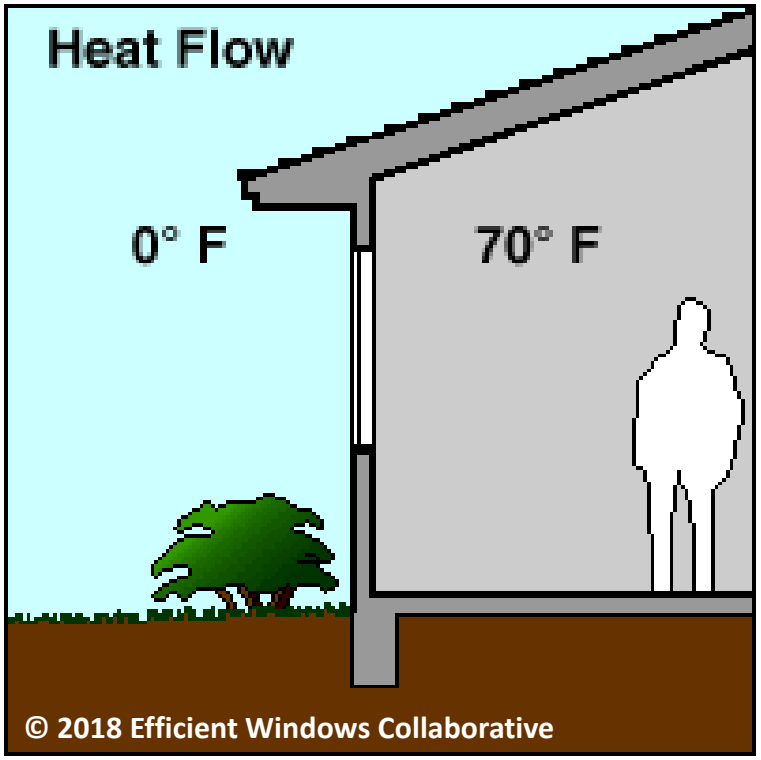
The percent of solar energy incident on the glazing that is transferred indoors both directly and indirectly through the glazing.

Visible Light Transmittance (VLT)

Radiant energy in the wavelength range of 380 nm to 780 nm. Percentage of incident visible light directly transmitted through the glazing.

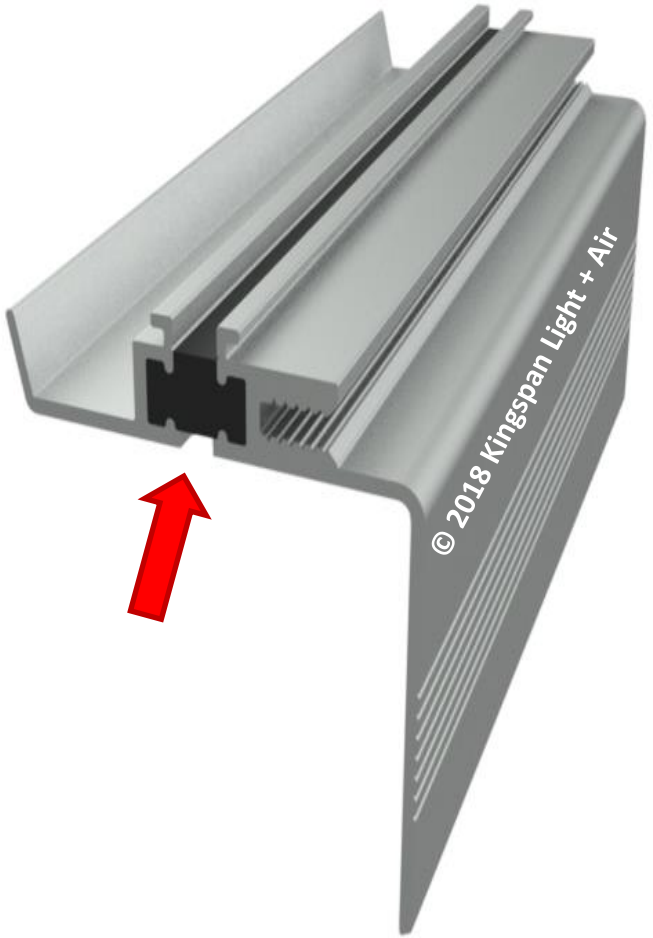
Thermal Efficiency
Don’t Confuse the U with the R…

R- Value is the measure of the resistance of the glazing to heat flow. It is determined by dividing the U-value into 1, (R-value = 1/U-value). A higher R-value indicates better insulating properties of the glazing. R-Value is not typically used as a measurement for glazing products and is referenced here to help understand U-value.



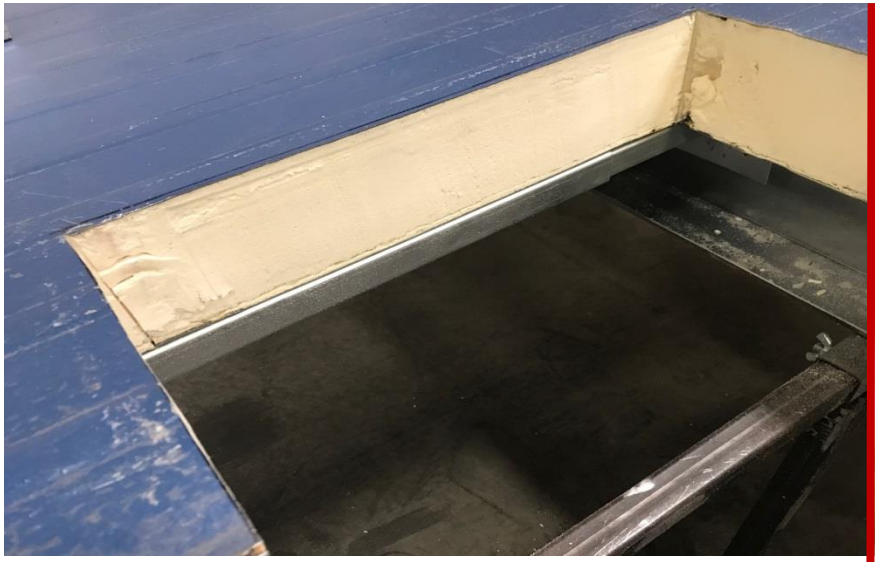
Thermally Enhanced Skylight Frames

- Thermal enhancements improve the U-value characteristics of finished systems.
- Thermally broken frames are made from resins that create a “thermal break” between the inner and outer surfaces of aluminum fenestrations.
- Thermal barriers reduce heat loss or heat gain through the aluminum.
- Developers, architects and designers are demanding better performance in terms of power usage to meet both customer requirements and newer, stricter government regulations.



Comparing Thermal Efficiency

Roofing System Performance



Insulated Metal Panel Roofs*

R-15 to R-43

U-0.07 to U-0.02

*Kingspan Kingzip © IMP System

Typical High-Clip PEMB Roofs**

R-10 to R-30

U-Not Published

**Owens Corning EcoTouch © Certified R Insulation

Comparing Thermal Efficiency

Roofing Systems Versus Skylights

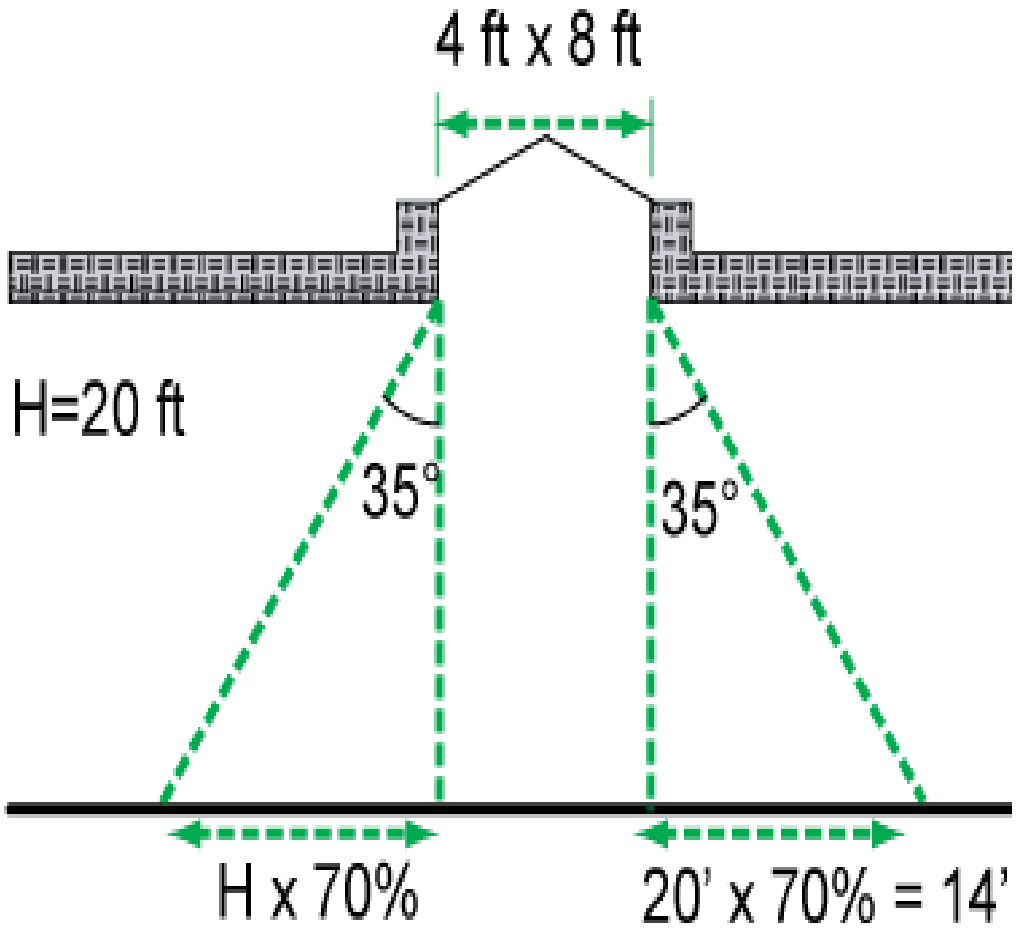
>

Skylights will never equal a roof's insulation value and still let light in…

Proper Daylighting Design Fundamentals

Daylighting Design – Calculate the Daylight Zone

- Light Travels at 35 Degree Angles
- Position skylights at approximately 1.4 x Mounting Height O.C.
- Skylight dimensions + 70% ceiling height (in each direction)

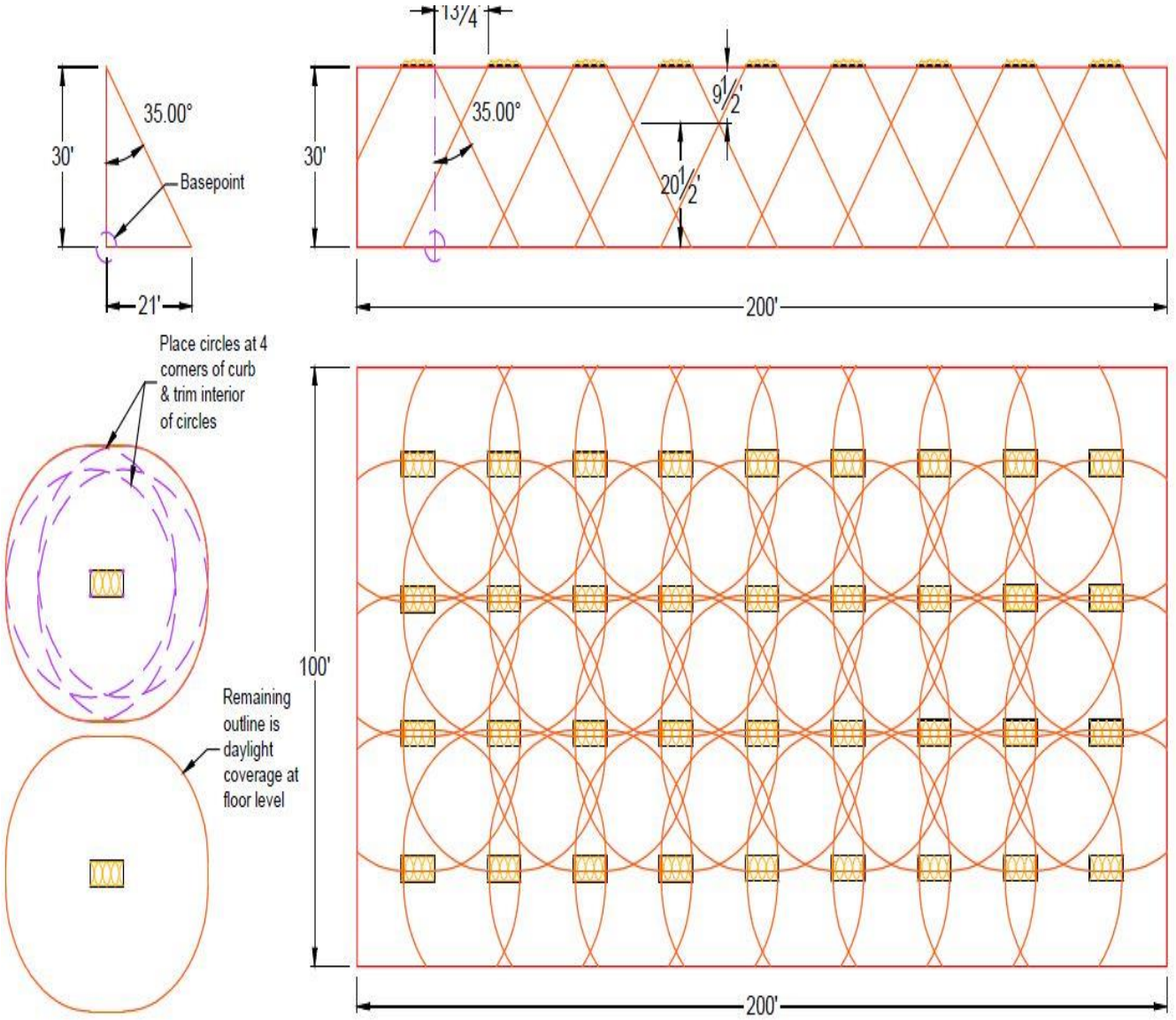


Example:

- 4 ft. x 8 ft. skylight
- 20 ft. x 0.70 = 14 ft
- Add 14’ to all sides of skylight
- Daylight Zone 32’ x 36’

Daylighting Design – Proper Placement

- The key is to overlap the throw of light to provide even illumination and avoid dark spots
- This illustration shows a concentric circle drawing that represents this concept



Daylighting Design – Determining Number of Skylights

Big Box Retail

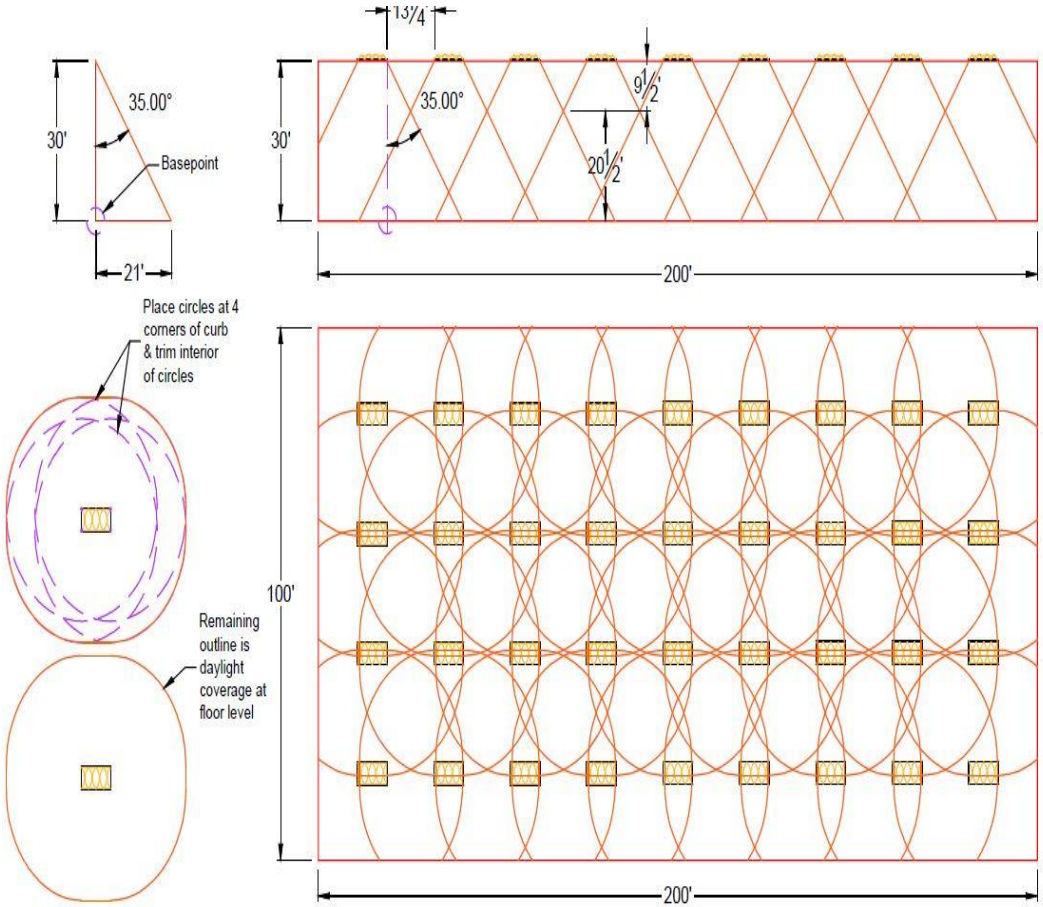
- Usually 5% of daylight area
- Example: 20,000 sq. ft. x 0.05 = 1,000 sq. ft. of skylight

Using 4’ x 8’ skylights

- 1,000/32 sq. ft. = 31.25 or 32 skylights for symmetrical layout

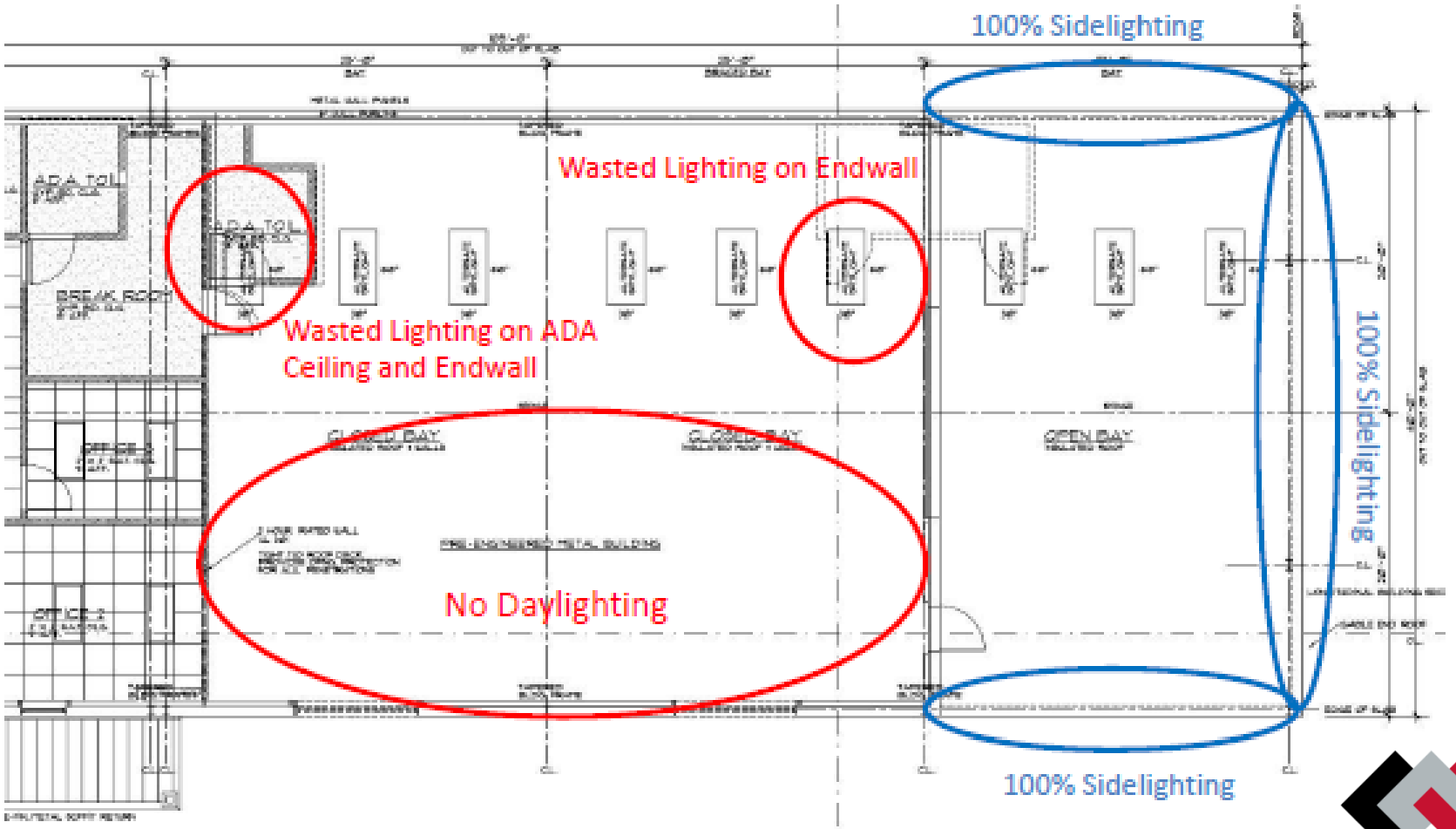
Using 2’ x 10’ skylights

- 1,000/20 sq. ft. = 50 skylights for symmetrical layout



Daylighting Layout Analysis

Small Building Example



Daylighting Layout Analysis

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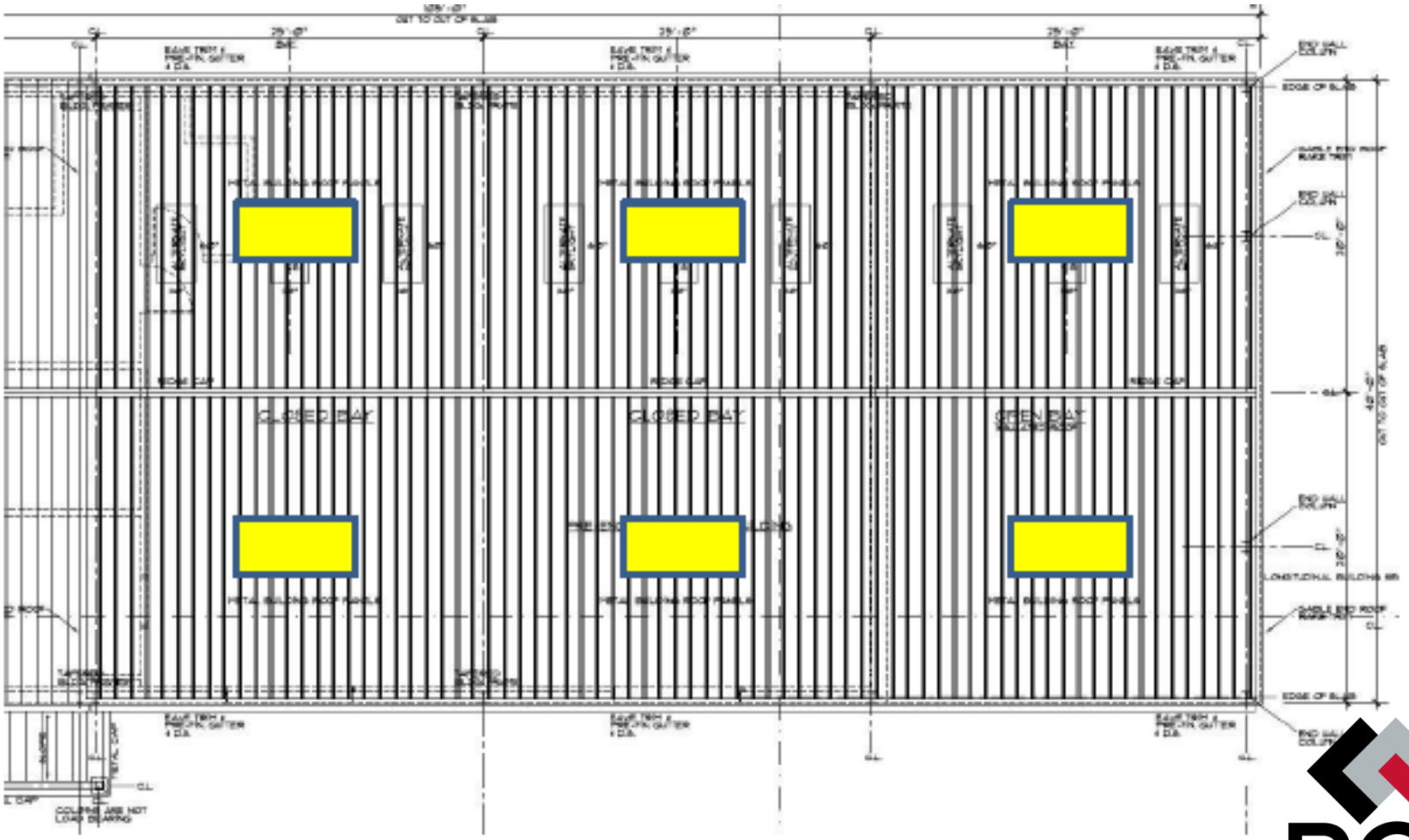


Daylighting Layout Analysis

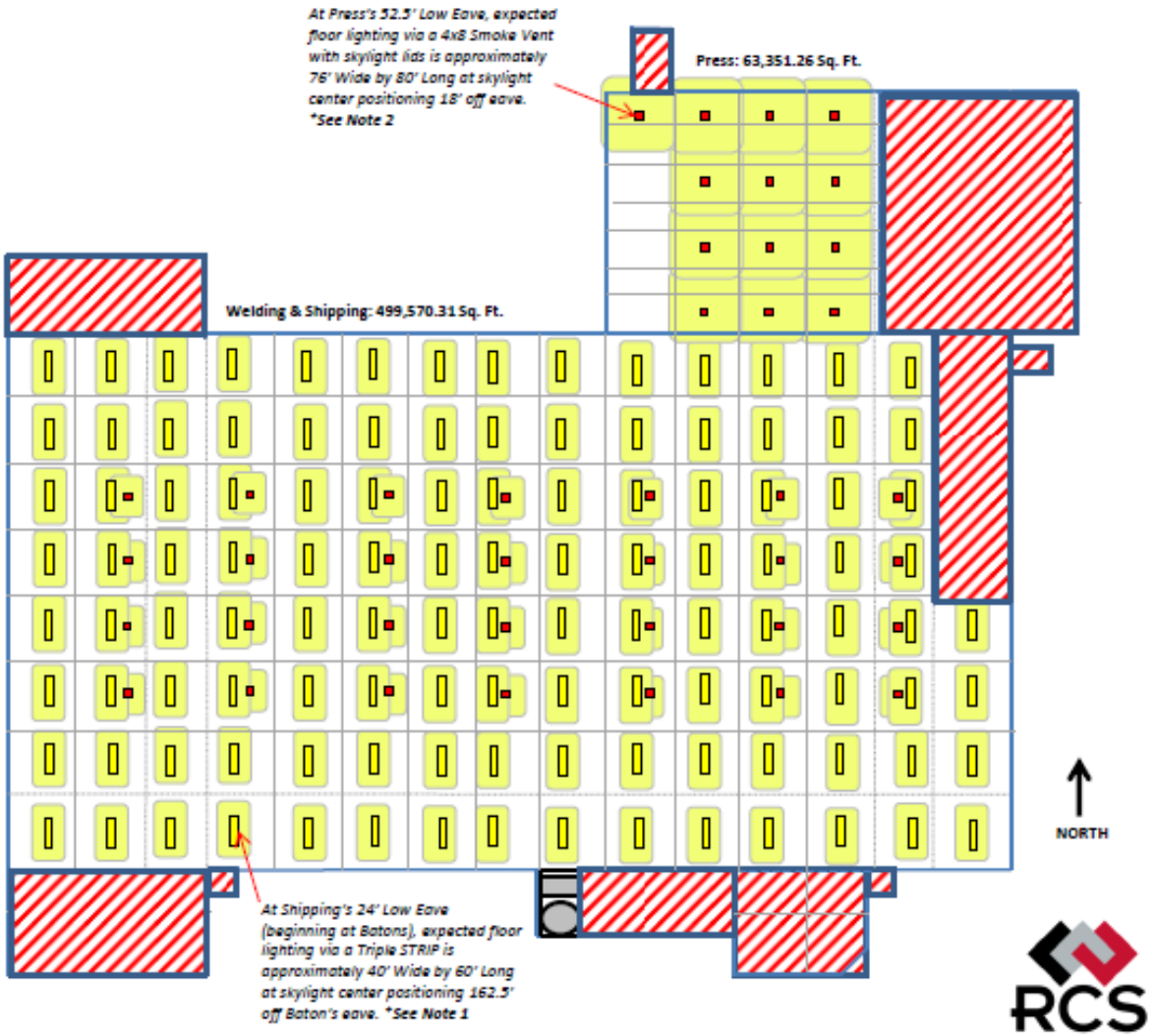
Large Building Example

Notes:

- Not to Scale
- Roof Slope is ¼:12
- Side-lighting analysis not incorporated
- Does not account for racking or equipment within buildings
- 1: This Triple STRIP position yields light coverage on the floor at 2,400 sq. ft. which illuminates 55.7% of a 65.625' X 65.625' bay
- 2: Due to the tall eave height, this smoke vent position yields light coverage on the floor at over 5,000 sq. ft. which illuminates 100% of a 65.625' X 32.8125' bay
- Although floor illumination increases with the slope of the roof, the overlays represent the dome locations indicated within the notes only for a conservative approach.
- **Dark spots will be prevalent in the Welding and Shipping with any <3% SFR layout. Additionally, the 0.5% layout of the Press area is significantly under-lit and the diagram should not misrepresent the amount of natural light in this building.**

Key

- Bay Line
- Skylight
- Building Footprint
- Interior Full-Height Wall
- Not Included in Daylighting Proposal
- 4x8 Fusible-Link Smoke Vent
- Approximate Natural Light on Floor Illumination



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Daylighting Layout Analysis

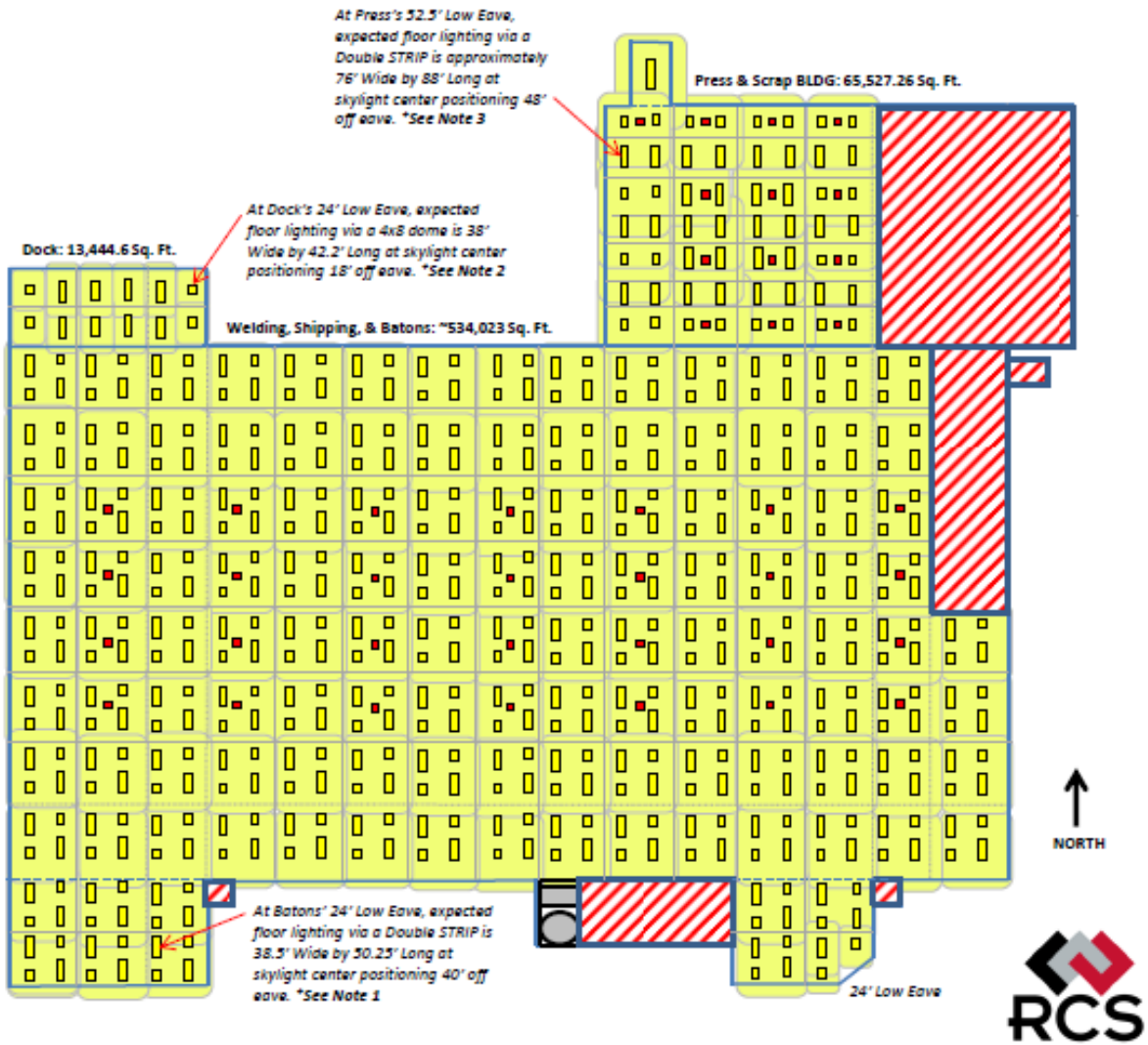
Large Building Example

Notes:

- Not to Scale
- Roof Slope is ¼:12
- Side-lighting analysis not incorporated
- Does not account for racking or equipment within buildings
- 1: This Double STRIP position yields light coverage on the floor at 1,934.625 sq. ft. which illuminates 44.9% of a 65.625' X 65.625' bay
- 2: This single 4x8 skylight position yields light coverage on the floor at 1,603.6 sq. ft. which illuminates 74.4% of a 65.625' X 32.8125' bay
- 3: Due to the tall eave height, this Double STRIP position yields light coverage on the floor at over 5,000 sq. ft. which illuminates 100% of a 65.625' X 32.8125' bay
- Although floor illumination increases with the slope of the roof, the overlays represent the dome locations indicated within the notes only for a conservative approach.
- **This 5% layout is ideal for an abundance of overlapping natural light on the floor and minimizing overall roof penetrations on the project.**

Key

- Bay Line
- Skylight
- Building Footprint
- Interior Full-Height Wall
- Not Included in Daylighting Proposal
- 4x8 Fusible-Link Smoke Vent
- Approximate Natural Light on Floor Illumination



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No Daylight Design Considerations

Properly Designed Daylighting System

SkyCalc™ Energy Modeling – Design Assistant

- Simple computer tool
- Microsoft Excel™ spreadsheet application
- Helps designers determine optimum toplighting strategy for maximum energy savings
- Uses simple data inputs (either common defaults or user-supplied data) to describe a building
- Produces graphs and charts that describe annual energy-use patterns

SkyCalc™ Generic Input and Results

SkyCalc: Skylight Design Assistant - Basic Inputs

Company Name: Centimark
Project Description: Smart & Final - Orange, CA

Design Skylight to Floor Ratio = 4.9%

Select Location Los Angeles (Coastal) CZ 6

Climate data loaded = Los Angeles CZ6.wea3
Climate data for location is already loaded

Skylights:

Number of skylights	34	
Skylight width	4	ft
Skylight length	8	ft

Max skylight spacing = 30 ft (1.5 x ceiling ht)

Skylight Description

Glazing type	Acrylic
Glazing layers	Single glazed
Glazing color	Medium white

Skylight Well

Light well height	1	feet
Well color	Off-white paint	
Safety grate or screen	● Yes, ● No	

Heating and Air Conditioning Systems

Air Conditioning	Mechanical A/C
Heating System	None

Utilities

Average Elec Cost	$0.180	kWh
Heating Fuel Units	Therm	
Heating Fuel Cost	$1.000	/Therm

Building

Building type	Retail	
Bldg area	22,050	ft²
Ceiling height	20	ft
Wall color	Off-white paint	

Shelving/Racks or Partitions?

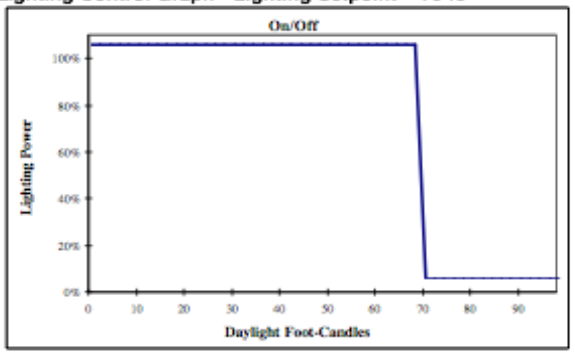
● Partitions, ● Shelves/Racks, ● None/Open

No data required	7	ft
No data required	4	ft
No data required	8	ft
No data required		ft

Electric Lighting

Lighting system	Open cell fluorescent	
Fixture height	17	ft
Lighting control	On/Off	

Lighting Control Graph - Lighting Setpoint = 70 fc



SkyCalc: Skylight Design Assistant - Graphic Results

Company Name: Centimark
Project Description: Smart & Final - Orange, CA

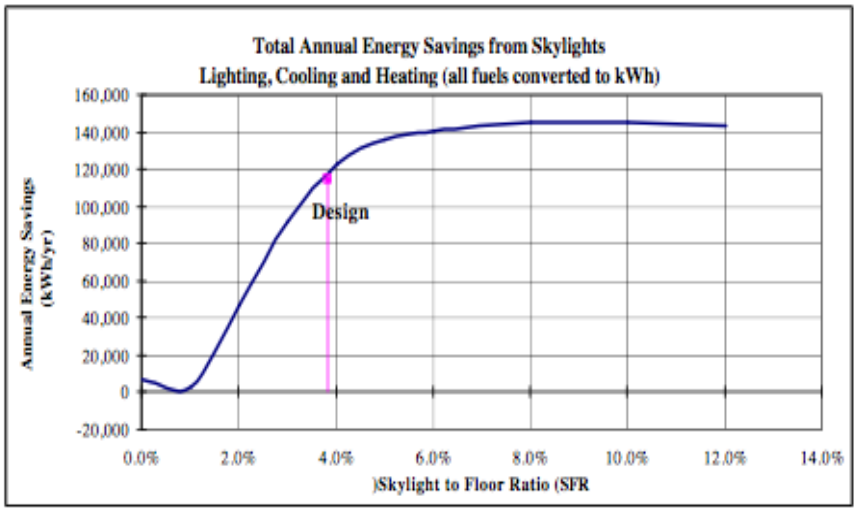
Dome Skylig … e Aperture = 2.07%, Skylight to Floor Ratio (SFR) = 4.93%

…ght footcandles (fc)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	8	39	72	98	113	114	99	76	42	10	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	20	58	98	127	142	142	129	103	66	29	2	0	0	0	0	0	0
Mar	0	0	0	0	0	0	8	40	82	123	155	175	180	168	140	98	50	10	0	0	0	0	0	0
Apr	0	0	0	0	0	2	26	66	110	150	178	191	189	180	151	115	66	22	0	0	0	0	0	0
May	0	0	0	0	0	7	40	78	123	163	193	208	210	201	175	136	87	37	4	0	0	0	0	0
Jun	0	0	0	0	0	11	44	82	124	161	186	203	209	203	179	143	95	45	9	0	0	0	0	0
Jul	0	0	0	0	0	6	40	86	135	176	201	218	218	214	191	152	100	50	8	0	0	0	0	0
Aug	0	0	0	0	0	3	28	69	124	166	197	212	215	203	177	134	83	32	1	0	0	0	0	0
Sep	0	0	0	0	0	1	15	51	98	141	176	195	197	184	151	103	50	10	0	0	0	0	0	0
Oct	0	0	0	0	0	0	8	39	77	112	138	155	155	138	106	62	19	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	2	23	56	89	111	122	119	102	72	36	6	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	10	40	70	92	104	102	89	63	31	4	0	0	0	0	0	0	0

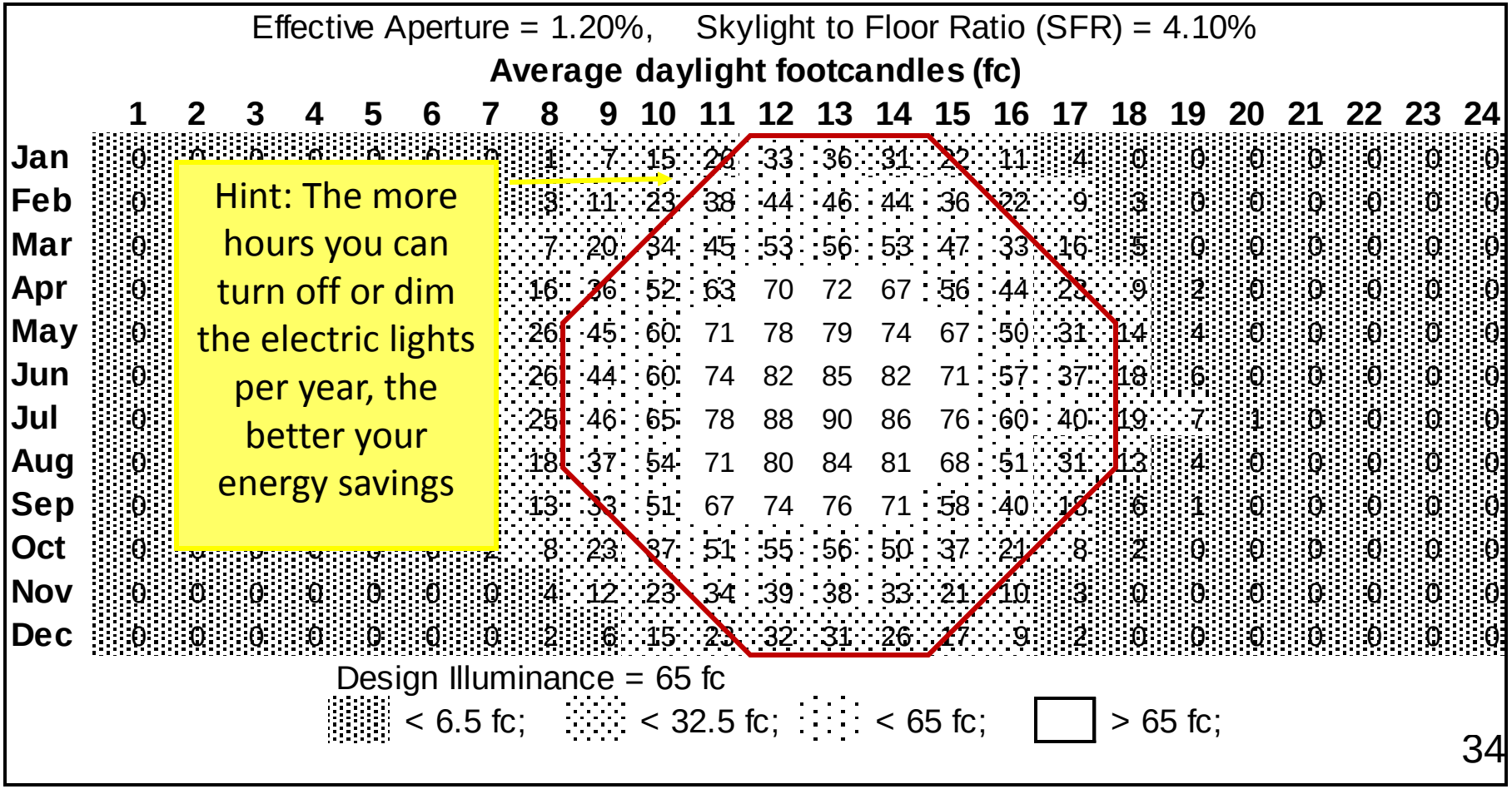
Design Illuminance = 70 fc
< 1 fc; < 35 fc; < 70 fc; > 70 fc;

Location = Los Angeles AP



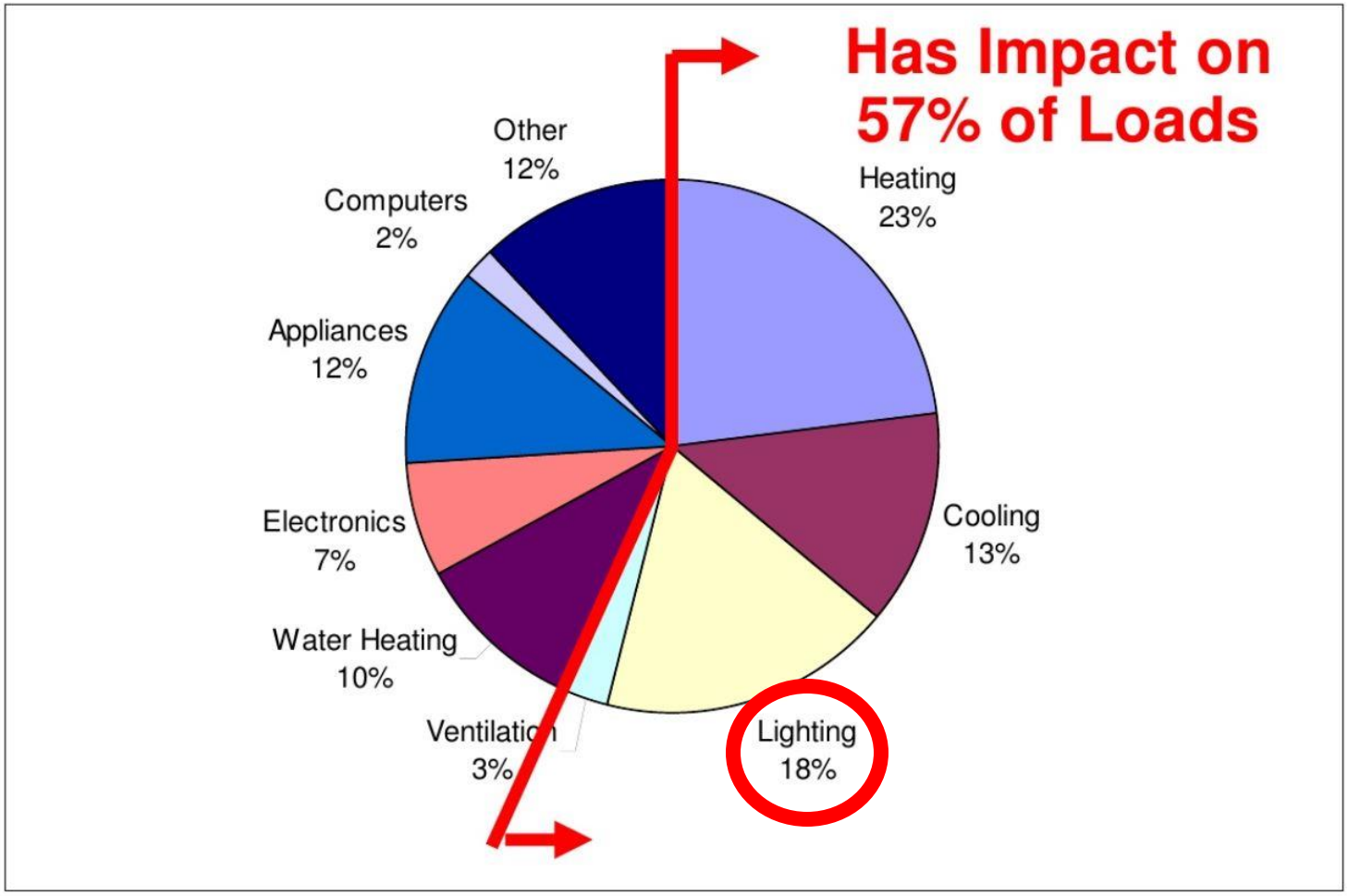
SkyCalc™ Predictive Modeling

SkyCalc™ predicts average hourly illumination, by month and time of day, for your given design.



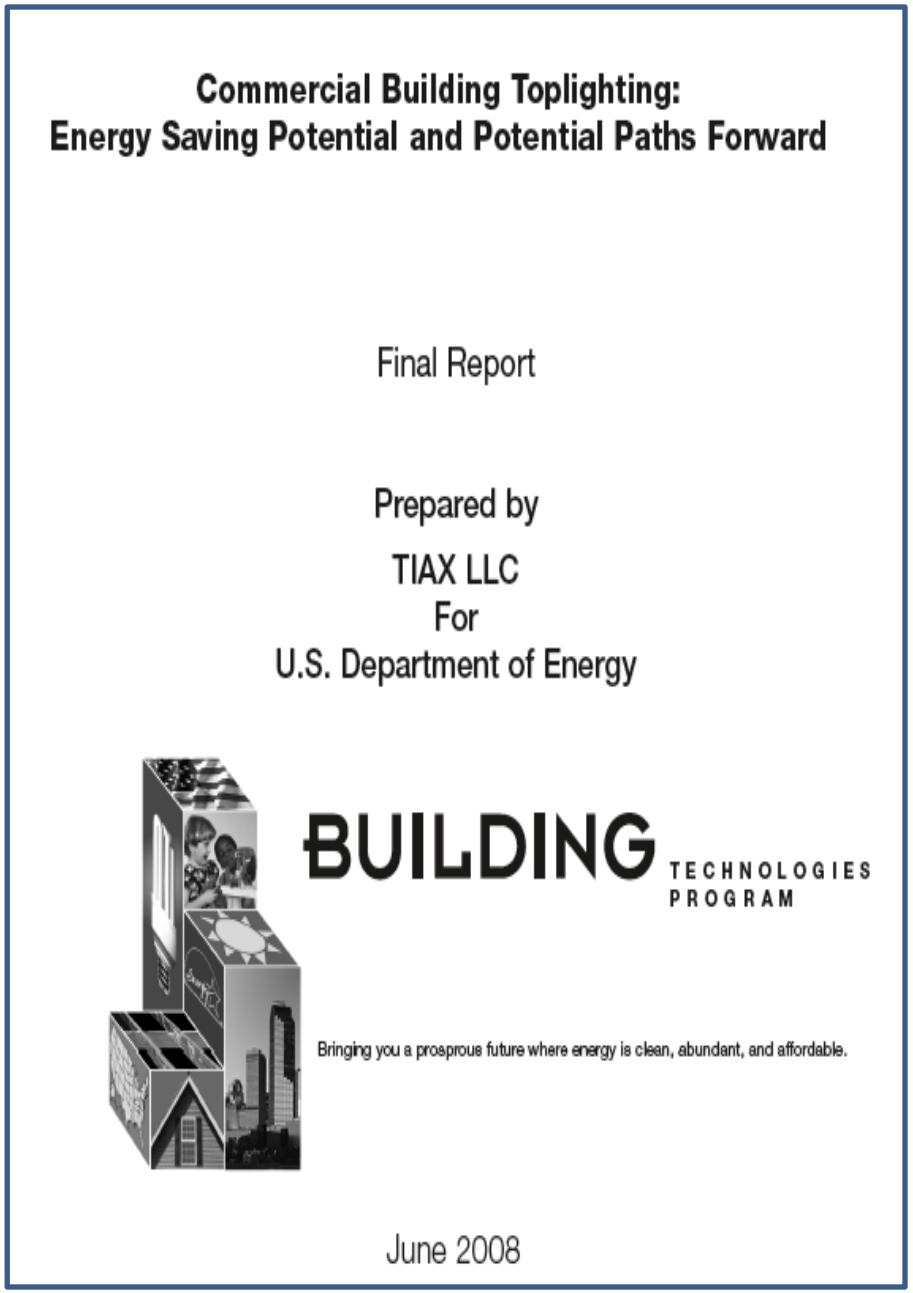
U.S. Department of Energy
Energy Efficiency and Renewable Energy

Building Consumption – Envelope Relationship



On average, 18% of all building electricity usage comes directly from electric lighting.

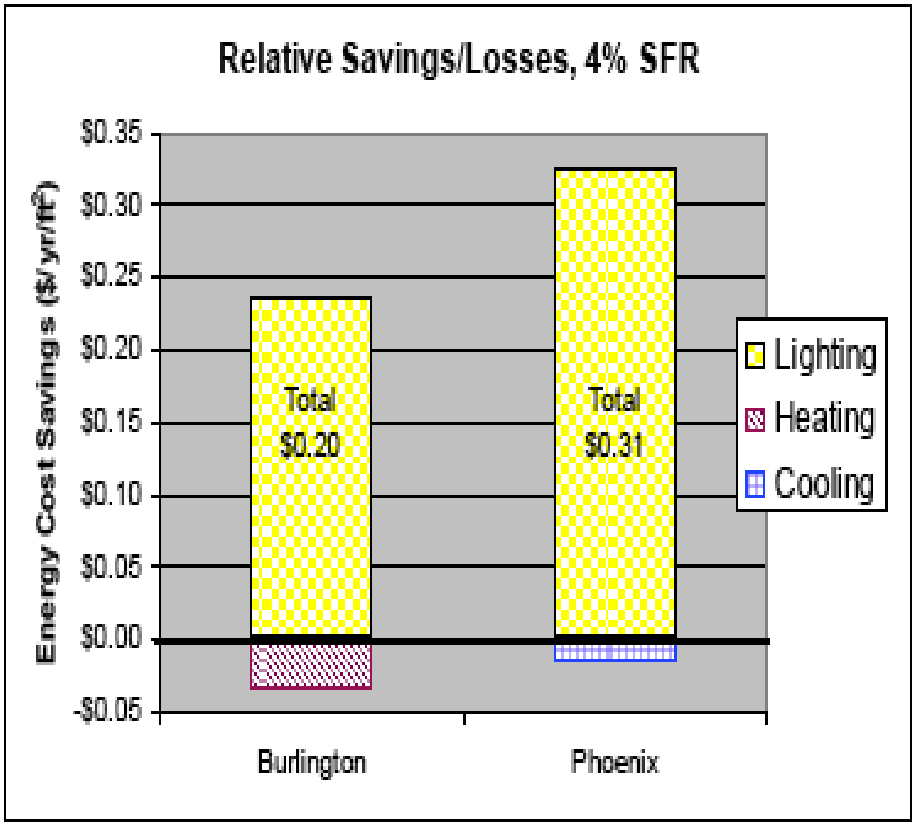
Source: U.S. Department of Energy 2016



TIAX Findings

- TIAX report delivered to the United States Department of Energy in 2008.
- Independent study of toplighting with skylights and how to achieve substantial energy performance through skylights even in the worst daylighting areas of the U.S.A.
- Defined the energy savings potential and potential paths forward that has influence all major building codes today.

TIAX Report Main Conclusion



Reduced lighting energy use ranks as, by far, the greatest factor in the annual savings at economically optimum SFRs.

The reduction in lighting energy use is directly related to VLT, Furthermore, the higher the VLT, the lower the total skylight area needed to achieve a given lighting energy savings. Lower total skylight area reduces cost and energy losses. **To further minimize energy *losses*, in most climates, the SHGC and U-Value of the skylight should be as low as possible. However, because heating and cooling energy losses are small relative to lighting energy savings, if reducing SHGC or U-Value results in any significant reduction in VLT it is generally not a beneficial tradeoff at SFRs in the range expected to be economically optimal, i.e., below 5%.**

Commercial Building Toplighting:
Energy Saving Potential and Potential Paths Forward

Final Report

Prepared by

TIAX LLC
For
U.S. Department of Energy

BUILDING TECHNOLOGIES PROGRAM

Bringing you a prosprous future where energy is clean, abundant, and affordable.

June 2008

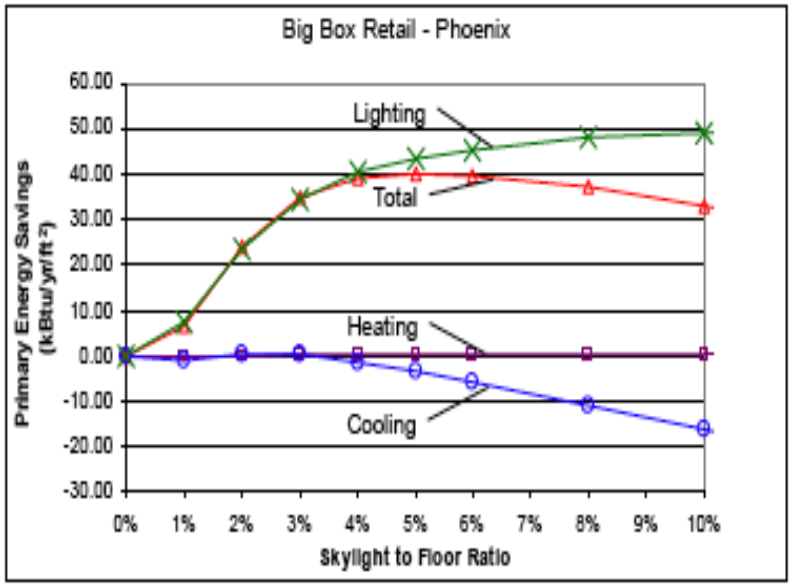


Figure 5-4: Annual Primary Energy Savings by End Use (lighting, cooling, heating) as a Function of SFR, Phoenix

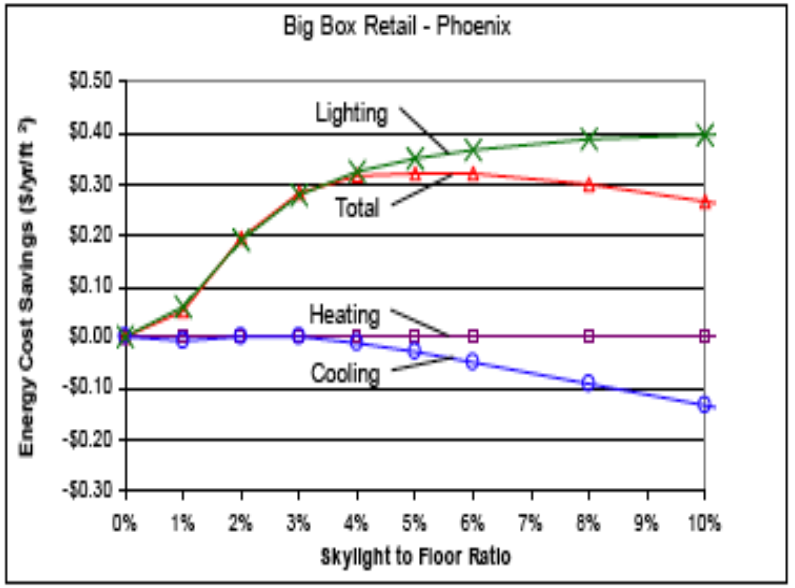


Figure 5-5: Annual Energy Cost Savings by End Use (lighting, cooling, heating) as a Function of SFR, Phoenix

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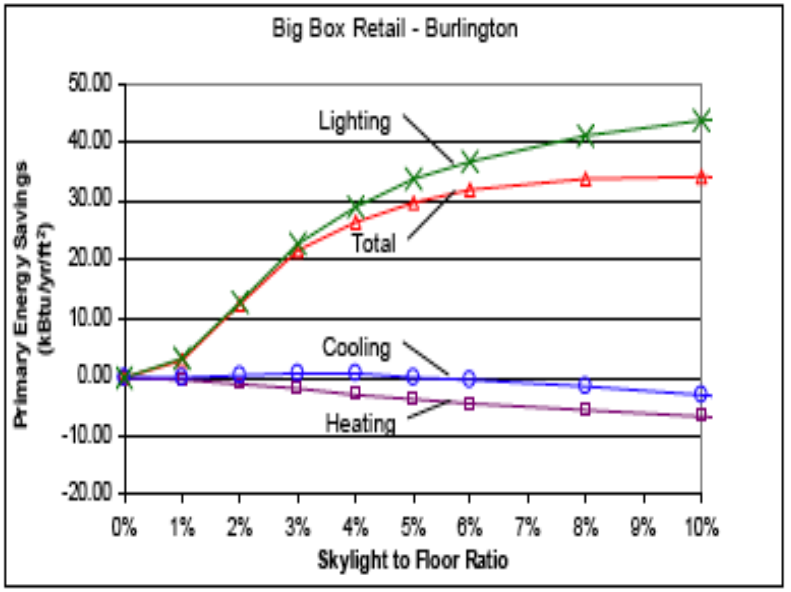


Figure 5-2: Annual Primary Energy Savings by End Use (lighting, cooling, heating) as a Function of SFR, Burlington

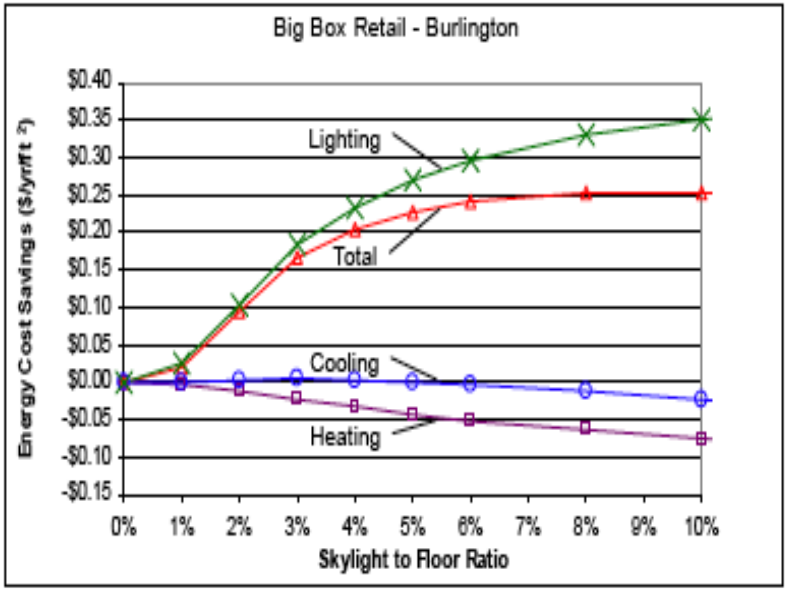


Figure 5-3: Annual Energy Cost Savings by End Use (lighting, cooling, heating) as a Function of SFR, Burlington

Skylights Don’t Save Energy!

Automatic Daylighting Controls Save Energy!

- Without lighting controls, skylights do not save energy.
- 3-Level Staging / Switching shown as very efficient. However, today dimming LED drivers are standard in commercial lighting.
- Proven that Simple On/Off switching leaves money on the table in energy savings!

The Power of Savings is when the lights are OFF

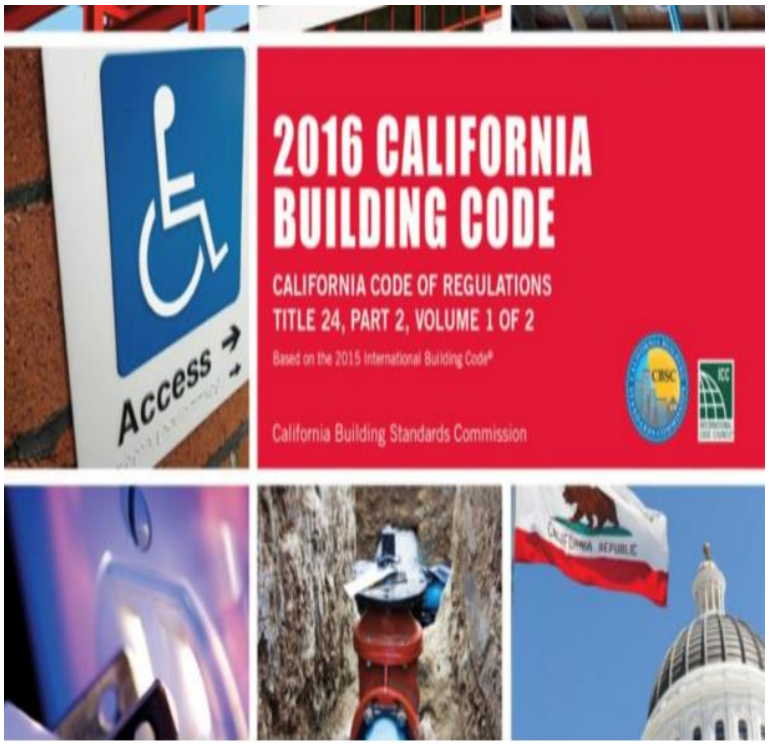
Welfare & The Environment - Energy

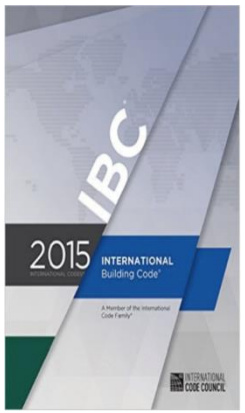
- The New Building Institute (NBI) – An Effective daylighting system complete with skylights, electric lighting and mechanical control systems can reduce building energy costs by as much as 35% to 65%.
- Department Of Energy (DOE) – Daylighting with control systems studies show 30% to 70% energy savings in **warehouses and distribution centers.**

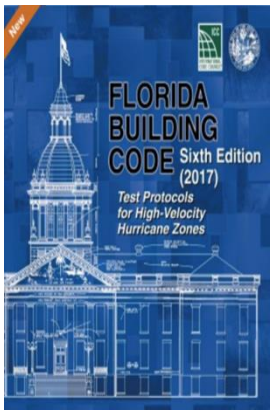
Code Driven Progress

Increased demand for better daylighting design:

- Energy Savings
- Life Safety
- System Longevity
- Fire Performance







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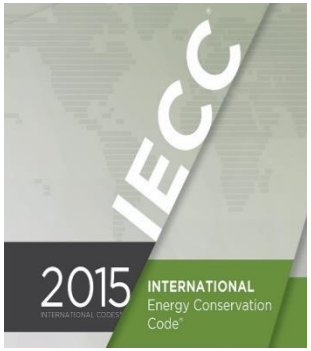


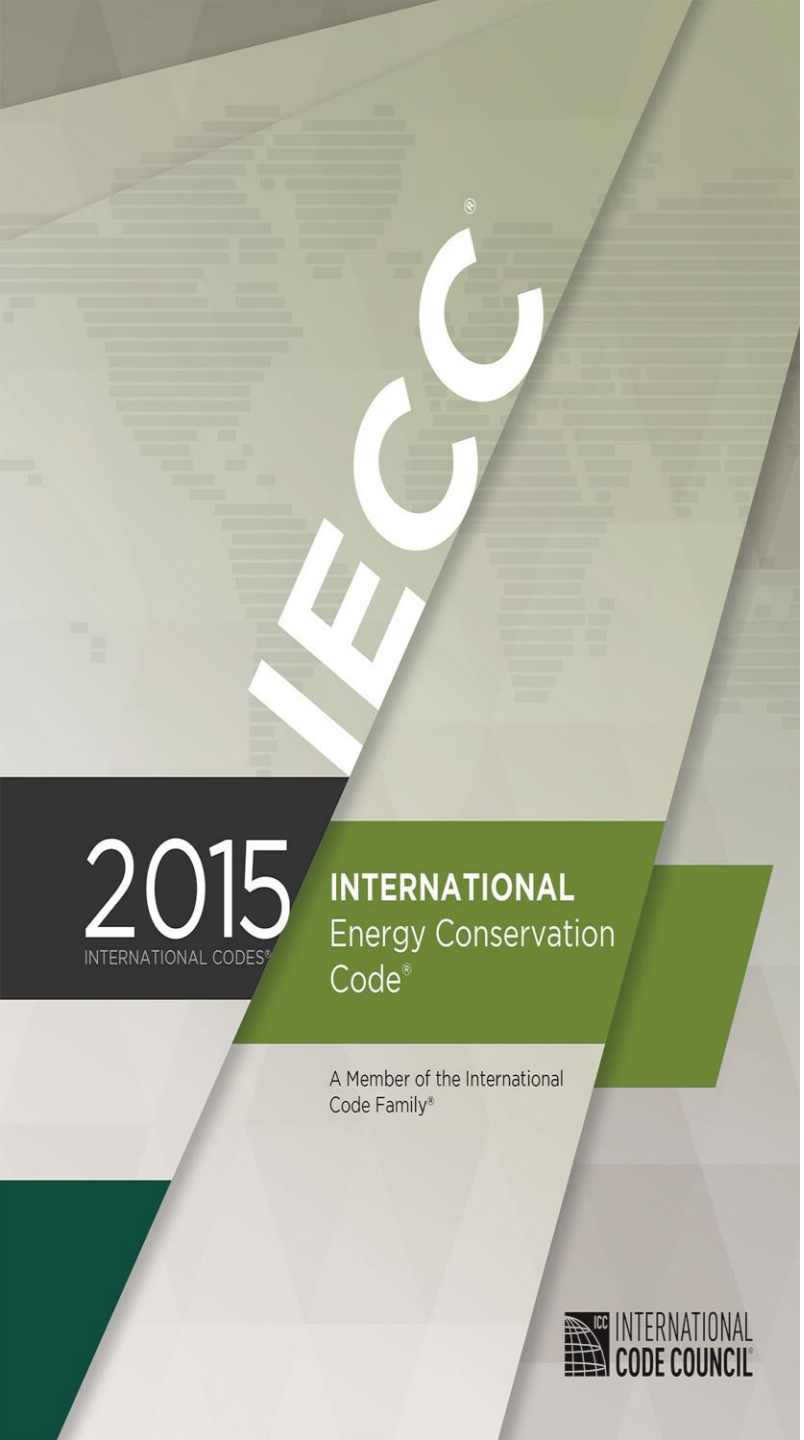
IECC 2015 – Table C402.3

Energy Codes are now affecting daylighting design.

CLIMATE ZONE	1	2	3	4 EXPECT MARINE	5 AND MARINE 4	6	7	8
Vertical Fenestration								
***U*-factor**								
Fixed fenestration	0.50	0.50	0.46	0.38	0.38	0.36	0.29	0.29
Operable fenestration	0.65	0.65	0.60	0.45	0.45	0.43	0.37	0.37
Entrance doors	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77
SHGC								

Orientation[a]	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N
PF < 0.2	0.25	0.33	0.25	0.33	0.25	0.33	0.40	0.53	0.40	0.53	0.40	0.53	0.45	NR	0.45	NR
0.2 ≤ PF < 0.5	0.30	0.37	0.30	0.37	0.30	0.37	0.48	0.58	0.48	0.58	0.48	0.58	NR	NR	NR	NR
PF ≥ 0.5	0.40	0.40	0.40	0.40	0.40	0.40	0.64	0.64	0.64	0.64	0.64	0.64	NR	NR	NR	NR
Skylights																
U-factor	0.75		0.65		0.55		0.50		0.50		0.50		0.50		0.50	
SHGC	0.35		0.35		0.35		0.40		0.40		0.40		NR		NR	

NR = No Requirement,
PF = Project factor.
[a] "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N". For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.



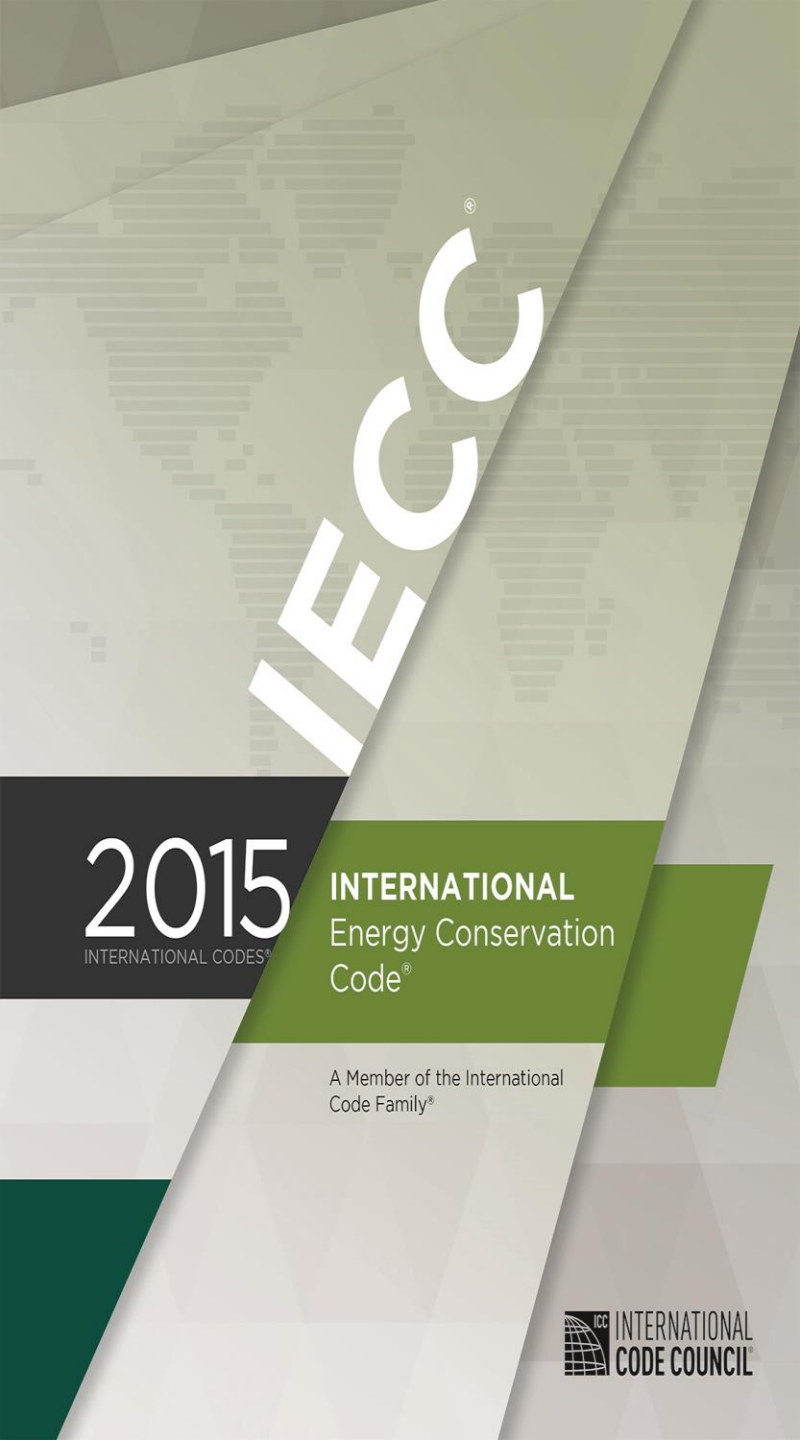
C402.4.1.2 Increased skylight area with daylighting controls. 5% Maximum of roof area provided automatic daylighting controls are installed in daylight zones.

C402.4.2 Minimum skylight fenestration area. In an enclosed space >2,500 SF, with 75% of ceiling heights >15' and used as a certain type of building, the total daylight zone under skylights shall be not less than half the floor area and shall provide a minimum skylight area to daylight zone under skylights of either:

1. Not less than 3 percent with a skylight VT of at least 0.40: or
2. Provide a minimum Skylight Effective Aperture (SEA) of at least 1 percent determined in accordance with Equation 4-4.

$$SEA = \frac{0.85 \times \text{Skylight Area} \times \text{Skylight VT} \times \text{WF}}{\text{Daylight zone under skylight}}$$

(Equation 4-4)



C402.4.2.2 Haze factor. In certain types of buildings – measured haze factor >90% (ASTM D1003).

C402.4.3.1 Increased skylight SHGC. When located above daylight zones with automated daylighting controls:

Climate Zones 1-6 = 0.60 max.

Climate Zones 7-8 = NR

C402.4.3.2 Increased skylight *U*-factor. When located above daylight zones with automated daylighting controls:

Climate Zones 1-3 = 0.90 max.

Climate Zones 4-8 = 0.75 max.

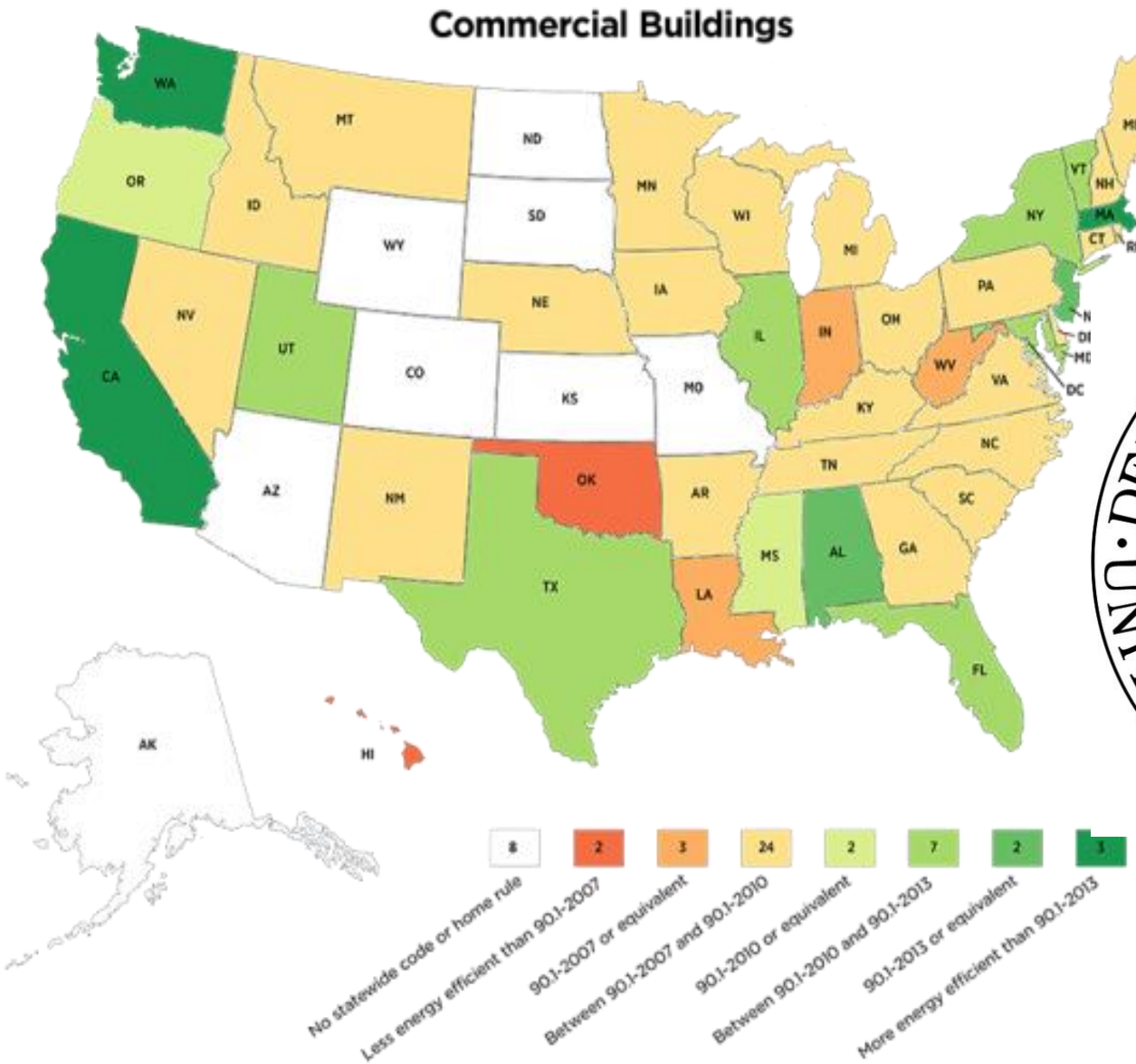
DOE - Federal Mandate For Energy Conservation

The United States Department of Energy is required by law (the Energy Conservation and Production Act, as amended (ECPA)) to issue a determination as to whether the latest edition of ASHRAE Standard 90.1 or the latest version of the International Energy Conservation Code will improve energy efficiency compared to the previous edition of the corresponding standard or code. DOE has one year to publish a determination in the Federal Register after each new edition of the standard/code is published.

09/26/14 – DOE issued a determination that ANSI/ASHRAE/IES Standard 90.1-2013 would achieve greater energy efficiency in buildings subject to the code.

Upon publication of an affirmative determination, States are required to certify that they have reviewed the provisions of their commercial building code regarding energy efficiency, and, as necessary, updated their codes to meet or exceed the updated edition of Standard 90.1. Additionally, DOE provides guidance to States on submitting certification statements and requests for deadline extensions. **State certifications for Standard 90.1-2013 must be submitted by 09/26/16.**

DOE - State Energy Code Adoption 01/2017



Skylight Safety Considerations

CFR 1910.23(e)(8)

- OSHA specifies a 200 lb. withstanding of loads, however different glazing materials have different impact resistance ratings
- Consider the degradation of strength over time: Safety screens and safety cages must be used.

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November 20, 2015

SAFETY ADVISORY

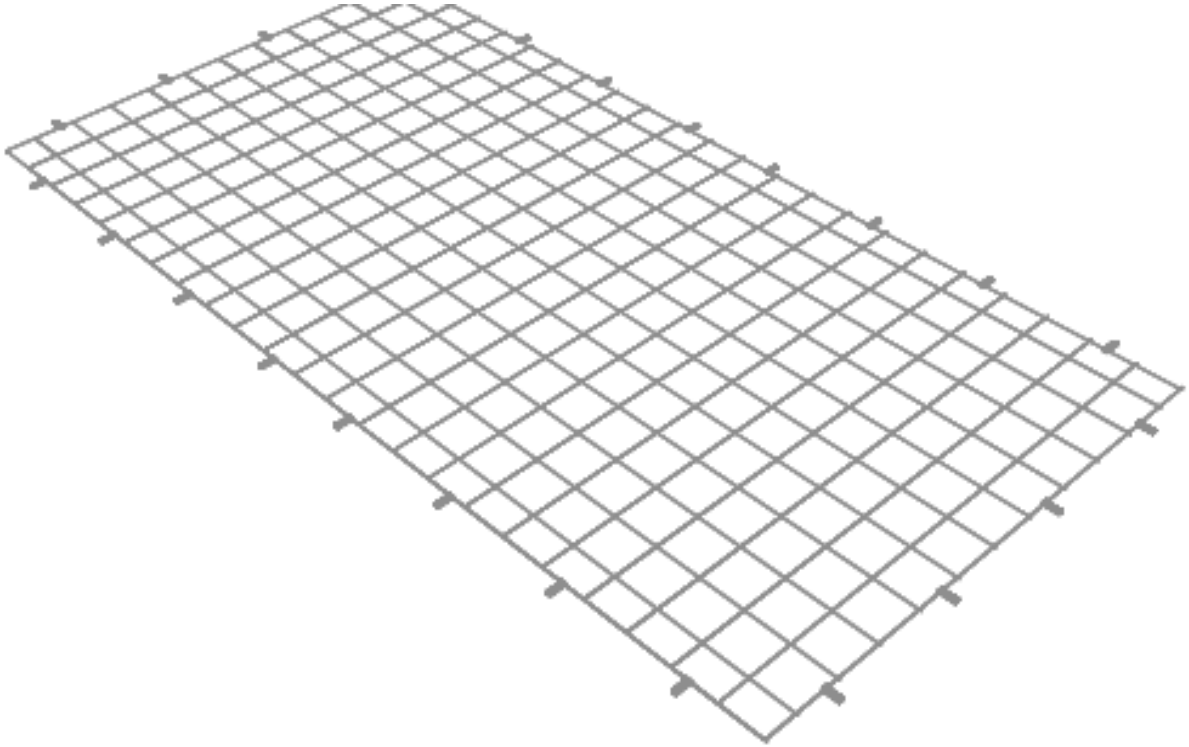
Fire Fighter Fatality Investigation and Prevention Program NIOSH

Translucent Corrugated Roof Panels May Contribute to Increased Fall Risk during Roof Operations

The National Institute for Occupational Safety and Health (NIOSH) recommends that all fire departments immediately take the following actions to reduce the risk of fire fighters being injured or killed while operating on roofs that contain translucent corrugated roof panels:

Translucent Corrugated Roof Panels commonly referred to as Light Transmitting Roof Panels are <u>NOT</u> the type of skylight referenced in this presentation.

Simple Solution: Skylight Safety Screen



Galvanized Steel Wire Mesh Safety Screen


Conclusion: Skylights save money when we apply performance, layout, lighting controls, and safety to building design.

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