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# Introduction to Unit Skylights for Daylighting of Commercial Buildings

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*A web-based learning course*



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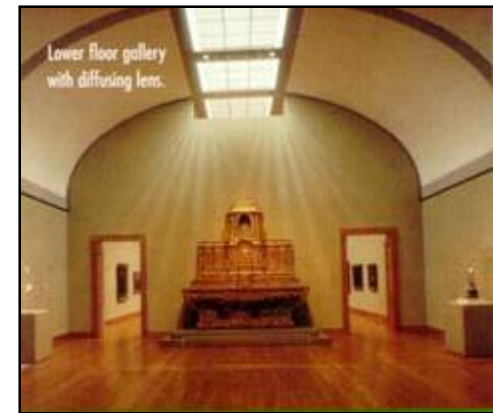
## Introduction to Unit Skylights for Daylighting of Commercial Buildings

### Welcome to the module!

- We will be covering the following topics briefly in the following slides:
  - What is daylighting?
  - Daylighting design strategies and benefits with unit skylights
  - How to complement daylight from unit skylights with electric lighting design and controls
  - Energy savings potential and analysis
  - Key specification issues
  - Examples and further resources
- Once you complete reviewing the module you can take a simple quiz and receive AIA continuing education credits

# Why use Skylights?

- Skylighting can be a form of art
- They also provide a means for sustaining life and growth
- Skylights provide vivid colors and high illumination levels
- Skylights can add life and variability to a dull space
- Skylights add high quality, dependable illumination for indoor spaces



# Skylights – why do we use them?

- Skylights can also be a design feature
- Skylights can enhance the building appearance
- Skylights can also enhance the performance of the people inside...
- In this module we concentrate on the use of unit skylights\* for uniform lighting in commercial and industrial spaces

\* Skylight assemblies that are modular, factory assembled and non-monumental in nature



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# Recent studies have shown that...

- Retail stores with unit skylights sell more
  - One chain of retail stores received 40% higher sales in its stores with unit skylights (all other things being equal)<sup>1</sup>
  - Another chain of retail stores received up to 2% more transactions and up to 6% higher sales in those stores with unit skylights<sup>2</sup>
    - Stores with the most daylight had the biggest effects
- Students perform better in daylight
  - Students in the San Juan Capistrano school district progressed 21% faster in classrooms with daylight compared to those without daylight <sup>3</sup>

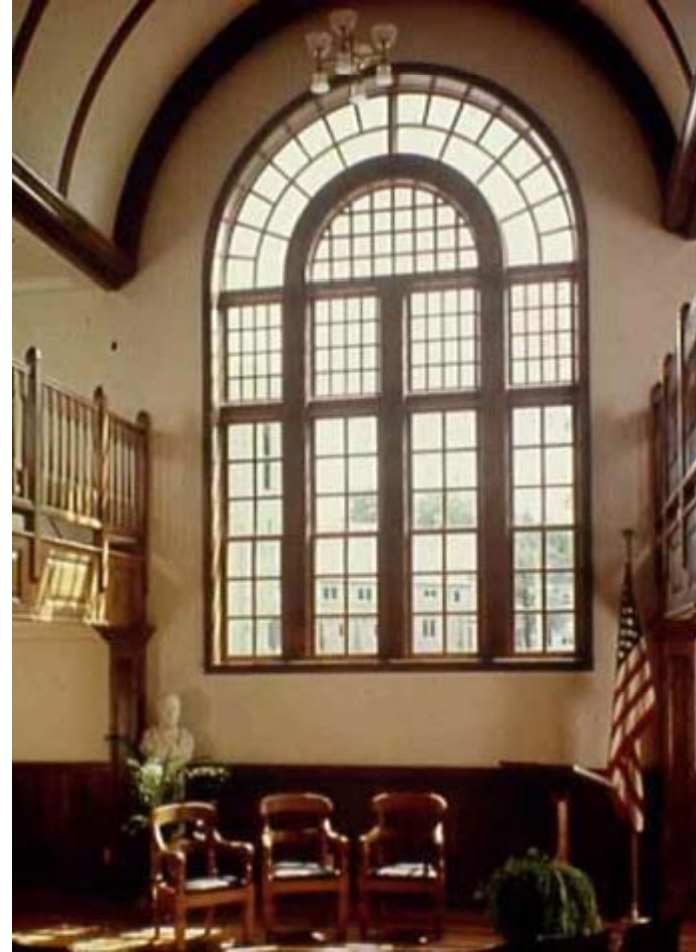
1. PG&E (1999). Skylighting and Retail Sales – [http://www.pge.com/003\\_save\\_energy/003c\\_edu\\_train/pec/daylight/daylight.shtml](http://www.pge.com/003_save_energy/003c_edu_train/pec/daylight/daylight.shtml)
2. CEC PIER (2003). Daylight and Retail Sales: Replication Study – <http://www.newbuildings.org/buildings.htm>
3. PG&E (1999). Daylighting in Schools - [http://www.pge.com/003\\_save\\_energy/003c\\_edu\\_train/pec/daylight/daylight.shtml](http://www.pge.com/003_save_energy/003c_edu_train/pec/daylight/daylight.shtml)

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# Before electric lighting....

...all buildings were  
daylit.

Just 50 years ago,  
almost all  
workplaces and schools  
were daylit !



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There has been a recent resurgence of interest in daylighting design.

There are two basic strategies:

1. **“Side-lighting”** from windows provides daylight along the perimeter of a building.
2. **“Top-lighting”** from the roof can provide daylight throughout the interior of a low rise building.



# Potential for unit skylight use

- We often think of daylighting only through windows...
- But the majority of commercial buildings in the U.S. are two stories or less
  - 60% of all floor area is underneath a roof and could be skylit

- Where is the most surface area?
- Where is it easiest to collect and control daylight?
- Through the roof with skylights!

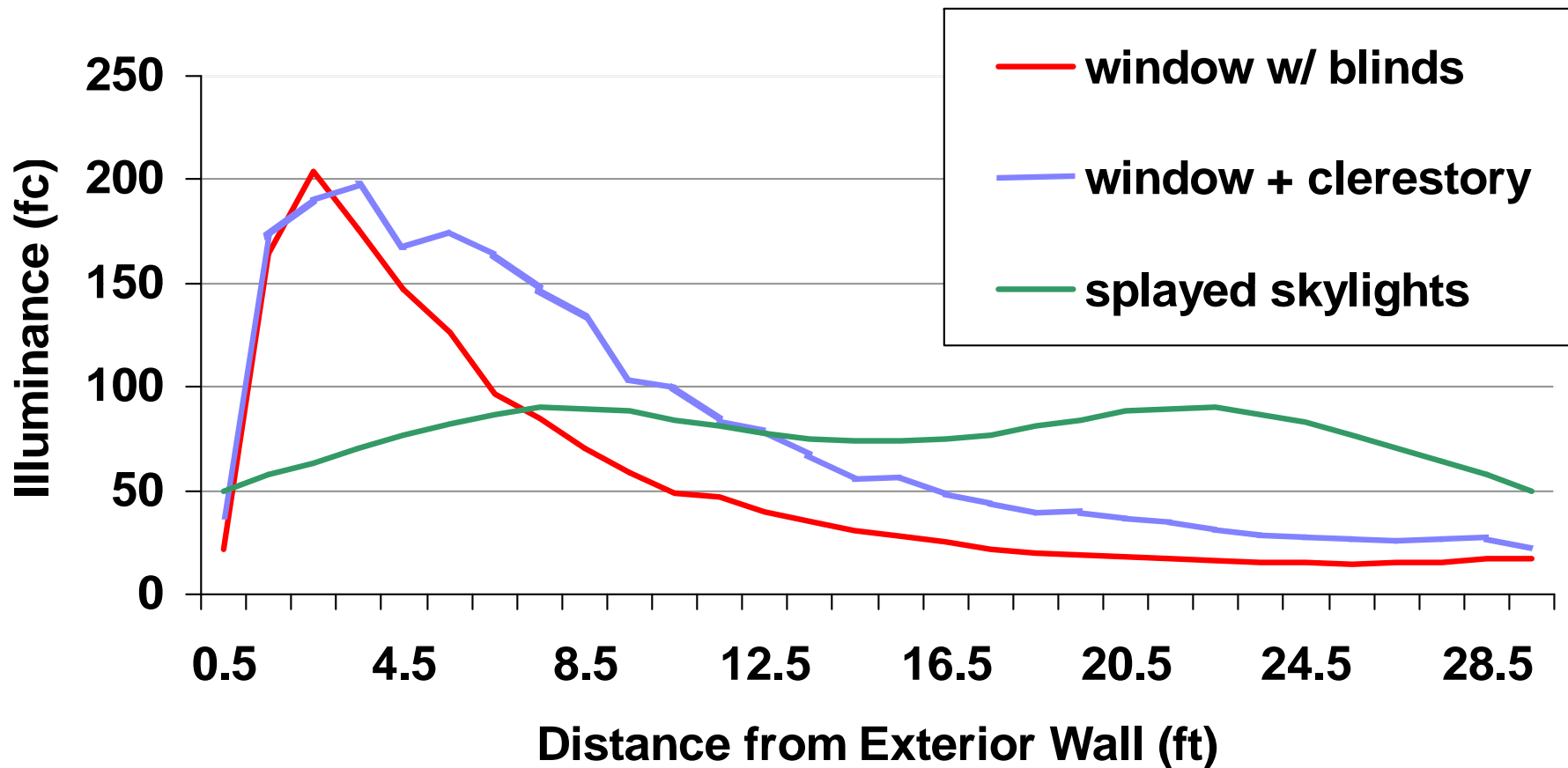


## Daylight illumination patterns from windows vs unit skylights

- Daylight penetration from windows is limited to a small distance from the window
- Adding clerestory can increase penetration of daylight in the space
- However, there is still non-uniformity in illumination of the space
- Unit skylights with splayed light wells provide the most uniform light in the space



Unit skylights provide more uniform illumination, and deeper into a room than windows

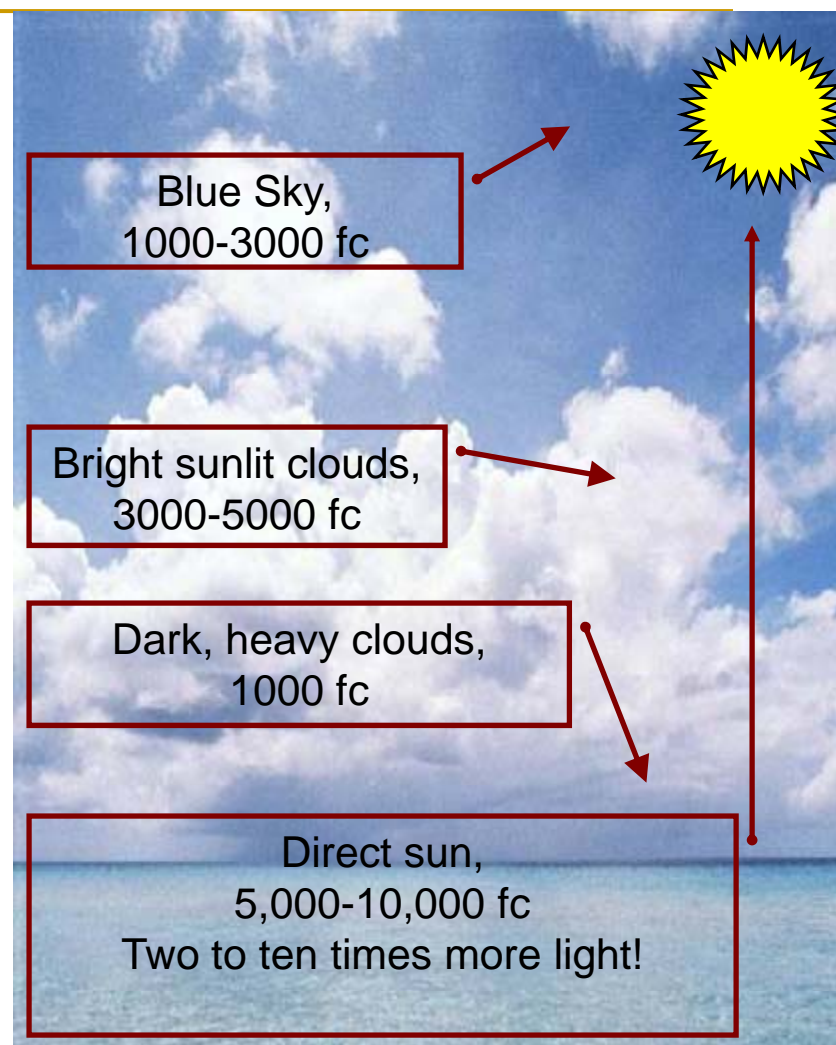


Source – Sectional analysis of a 30 ft wide space using Lumen Micro, a software tools that allows you to create and simulate lighting layouts for both indoor and outdoor applications

# How much light?

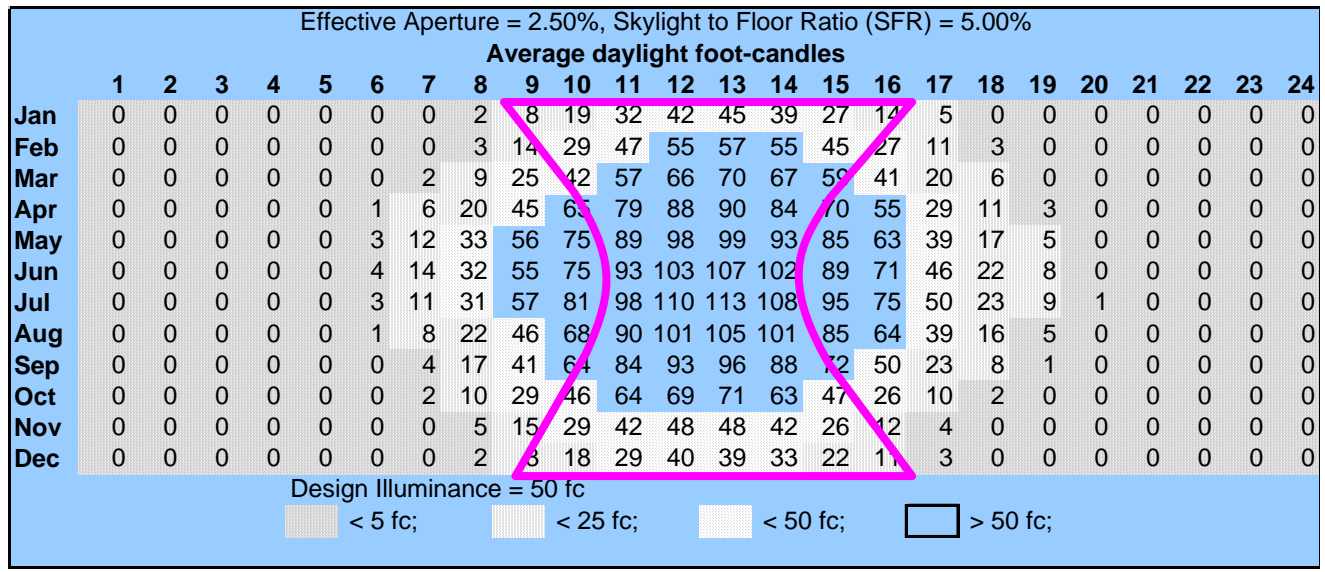
- Windows provide daylight from the sky
  - It is important to shade the windows from the sun to avoid excessive glare
- Unit skylights use sunlight in addition to daylight
  - By diffusing the sunlight we avoid the glare problems we have with some windows
  - Even on a cloudy day, the sky is three times brighter straight up than on the horizon!
- Thus, a unit skylight can easily be three to ten times smaller than a window or roof monitor\* while collecting the same amount of daylight

\*A roof monitor is vertical or near vertical glazing above the level of the adjacent roof.

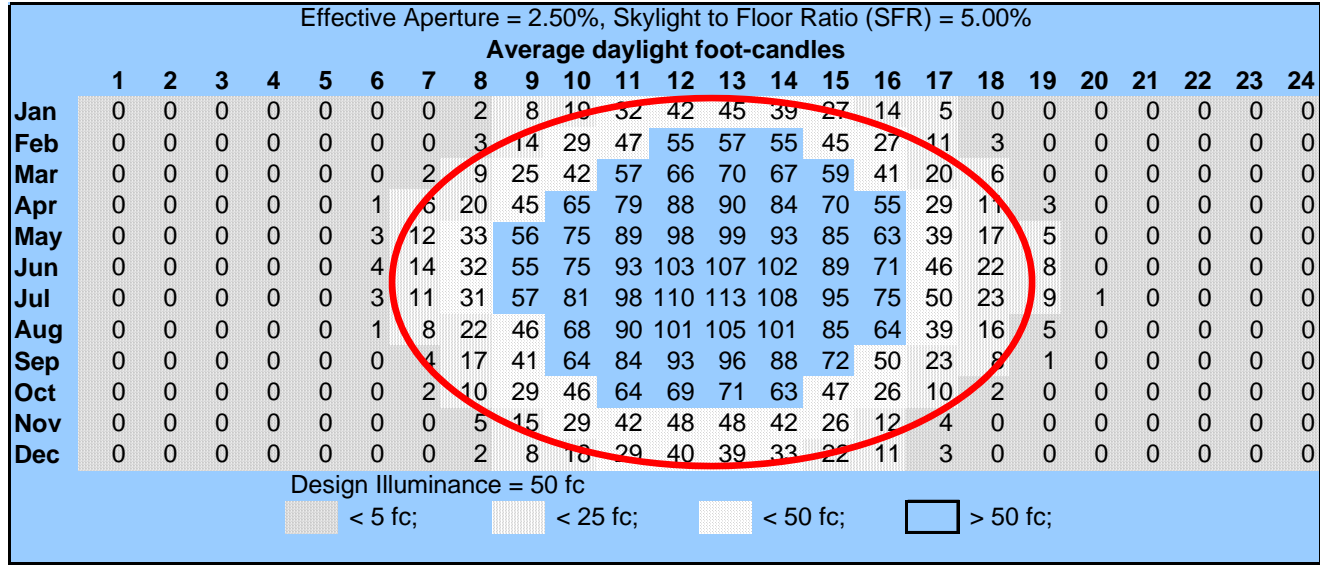


*fc = foot candles – a measure of illumination from a light source*





South facing roof monitor

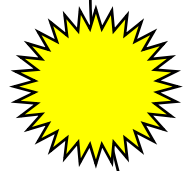


Skylight

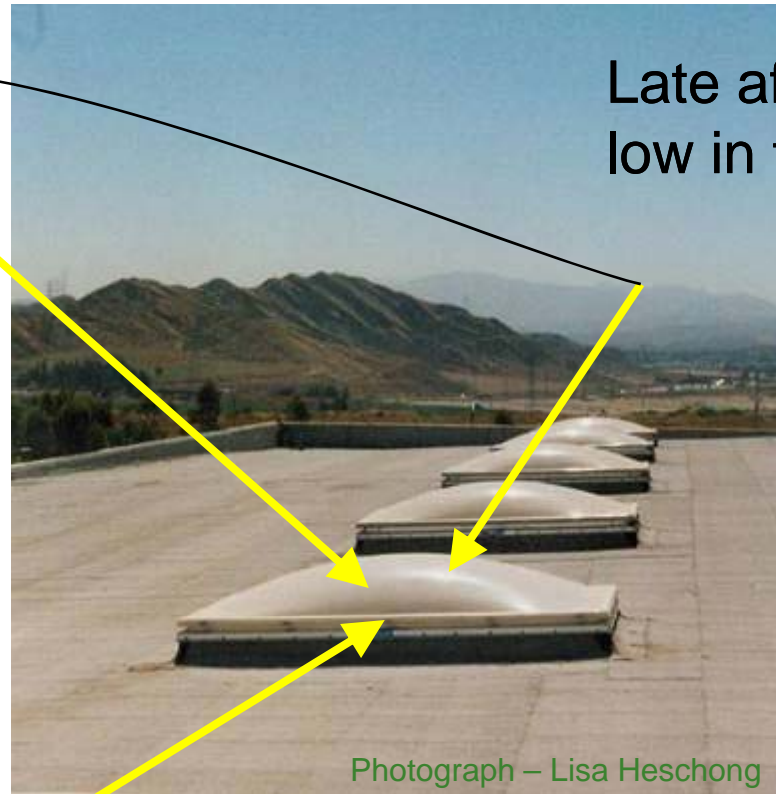
This is because unit skylights receive both sunlight and daylight all day long, especially in the more critical early morning and late afternoon hours

Mid-day, high in the south

Late afternoon, low in the west



Early morning, low in the east



Photograph – Lisa Hescong

# The Skylighting System

- The term “**skylighting system**” is used to refer to an illumination system that includes skylights, electrical lighting controls and a building explicitly designed to optimize the distribution of daylight
- A successful skylighting system design involves coordination of both architectural and electrical components, such as:



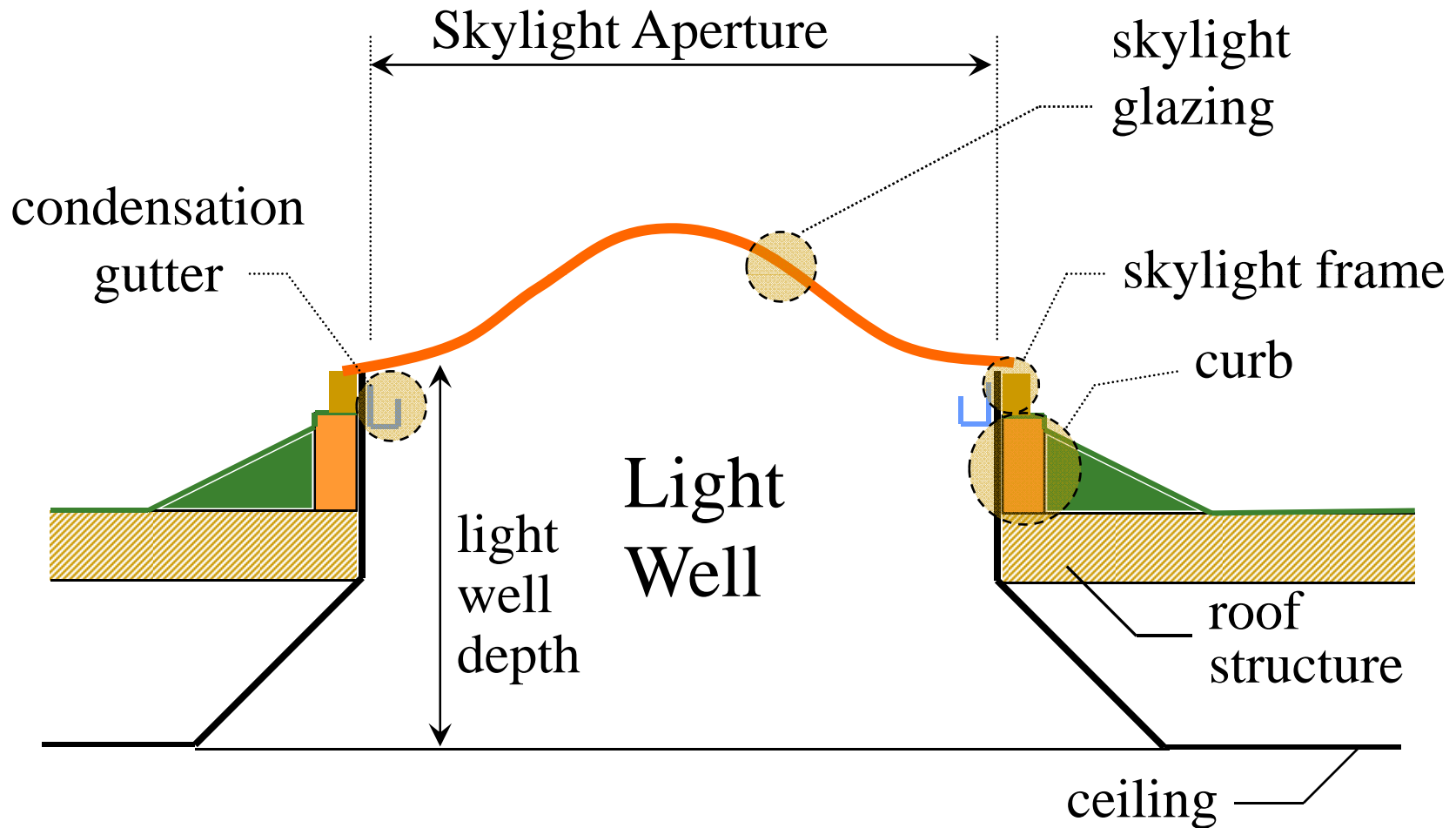
- **Unit skylights**
  - Glazing characteristics
  - Layout
  - Light well shape
  - Skylight shading devices
- **Building characteristics**
  - Ceiling height
  - Color of surfaces
  - Shelving and partitions
- **Electric lighting system**
- **Lighting controls**

# But don't skylights leak?

## ***Not any more!***

- In the old days, when skylights had to be custom built on-site, some of the glazing joints did not age well and eventually leaked
  - This gave all skylights a bad reputation for leaks
- Modern unit skylights use factory-formed components that are designed, tested, and certified to resist uncontrolled water infiltration
  - New caulking and gaskets are also designed for long lives
- Often, water stains from condensation dripping off the glazing is mistaken for a leak
  - Condensation gutters at the bottom of skylight glazing are designed to temporarily collect condensation and prevent it from causing water stains
- The most common reason skylights are reported to leak is poor installation of the roofing material at the skylight curb
  - Good construction practices and roofing warranties prevent this problem
  - Follow AAMA's Skylight Installation Guide to avoid construction problems

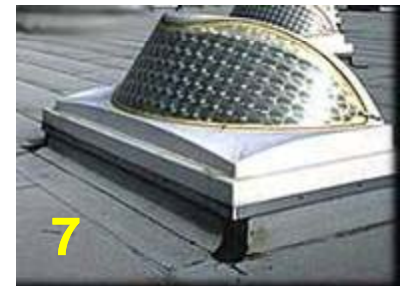
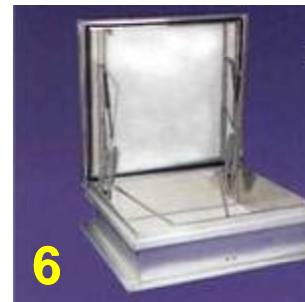
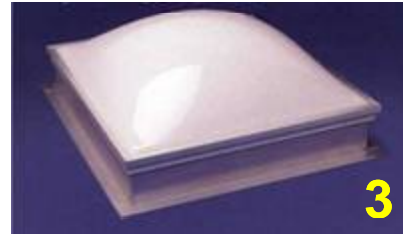
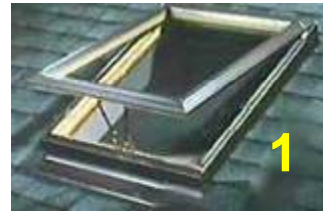
# Nomenclature: Unit Skylight System Components



# Unit skylight shapes

Unit skylights come in various shapes and sizes:

1. Flat
2. Parabolic
3. Domed
4. Vaulted
5. Ridge
6. Smoke Vents
7. Custom geometry



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# Unit Skylight Glazing Materials

- Common glazing materials for unit skylights include:
  - Glass
    - Tempered
    - Laminated
    - Sand Blasted
    - Low-e
    - Chemical Etched
    - Ceramic Frit
  - Plastics
    - Acrylic
    - PolyCarbonate
    - Fiberglass
      - Molded Sheet
      - Insulated panel
    - Co-polyesters
- Each of these materials come in a variety of colors, thickness, strength and number of layers
- The choice of glazing properties affects the amount of light coming through the skylight, how well the light is diffused, and other aspects of its durability and energy performance

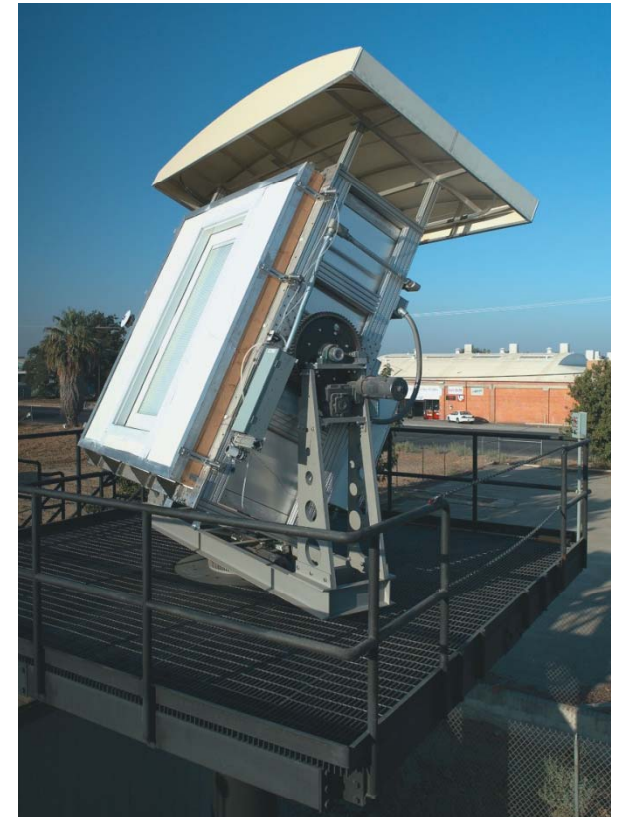
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# Unit Skylight Glazing Properties

- The choice of glazing material can have enormous impact on the quality of light provided and energy efficiency of design
- Factors to consider include:
  - **Visible Transmittance** ( $T_{vis}$  or VT) – Measures how much light comes through a product; an optical property that indicates the amount of visible light transmitted.
  - **Haze Factor** – Haze is the ratio of diffusely transmitted light (scattered more than  $2.5^\circ$ ) to the total transmitted light of a glazing. Diffused light provides more even light dispersion. (100% haze factor would equate to 100% of light being diffused. Many building codes require skylights to have a minimum 90% haze factor.)

# Unit Skylight Glazing Properties

- Additional factors to consider include:
  - **Solar Heat Gain Coefficient (SHGC)**  
A measurement of how well a product blocks heat from the sun. The fraction of incident solar radiation admitted through the glazing, both admitted through and directly transmitted, and absorbed and subsequently released inward. The lower a product's SHGC, the less solar heat it transfers.
  - **Thermal Conductance (U-factor)**  
A measurement of how well a product prevents heat from being transmitted. The lower the U-factor, the better the product's insulating value. The reciprocal is the Thermal Resistance or R-value.



Skylights with unique glazing options may require physical testing as shown in this solar calorimeter.

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## To achieve efficient illumination in a space, the designer should:

- Diffuse the light broadly
- Insist upon light colored surfaces throughout the building – ceiling, floor and walls
  - Paint everything in the ceiling white for best performance
- Size the unit skylights appropriately
- Space unit skylights evenly
- Use an efficient light well design when needed
- Consider ways to avoid glare and “dim the daylight” when necessary

# Why is diffusion so important?

- As we learned earlier, skylights are designed to utilize sunlight...
  - But natural sunlight is too bright for comfort
  - “Hot spots” of excessively bright light will cause thermal discomfort, local melting of frozen products, and interference with laser scanners



Overly bright spots cause glare and visual discomfort

Pooling too much light in one place is not an efficient use of daylight

# A diffusing unit skylight provides high quality, uniform light throughout the space

There are many ways to achieve diffusion:

- ❑ Glazing properties
- ❑ Louvers
- ❑ Light well shape
- ❑ Diffuser at bottom of well
- ❑ Banners
- ❑ Structural elements



# Paint Your Ceilings White

White ceilings greatly increase the light levels, increase system efficiency and reduce contrast glare



# In buildings with a dropped ceiling, unit skylights require a “skylight well”

- Skylight wells have two essential parts:
  1. A “throat” that helps to move the light as efficiently as possible through the plenum space, between the top of the roof and the bottom of the ceiling

Examples of pre-manufactured “throats”



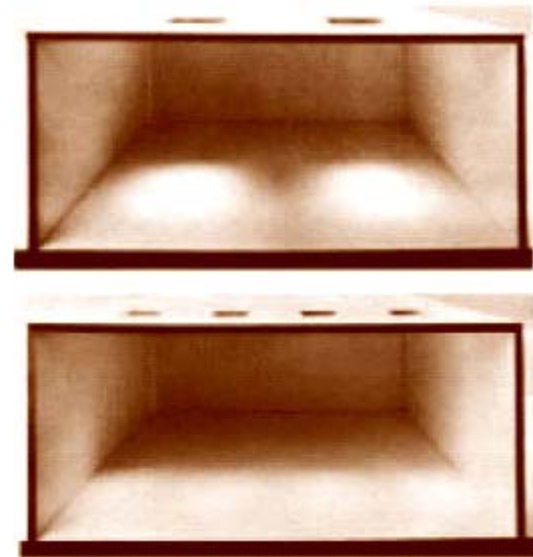
- The second part of a light well, the “**splay**,” allows the daylight to spread as broadly as possible
  - And reduces glare by creating a surface similar in brightness to the ceiling



For more information download *Modular Skylight Well Guidelines*- <http://www.energydesignresources.com>

# Unit Skylight Size Rules of Thumb

- There are many tradeoffs
  - between more but smaller, vs.
  - fewer and larger unit skylights
    - in a space for the same SFR and glazing characteristics
- There is no ideal size for unit skylights
  - Size selection depends on the
    - Height of the daylit space
    - Tasks performed in the daylit space
    - Daylighting requirements of the space
    - Construction and cost constraints

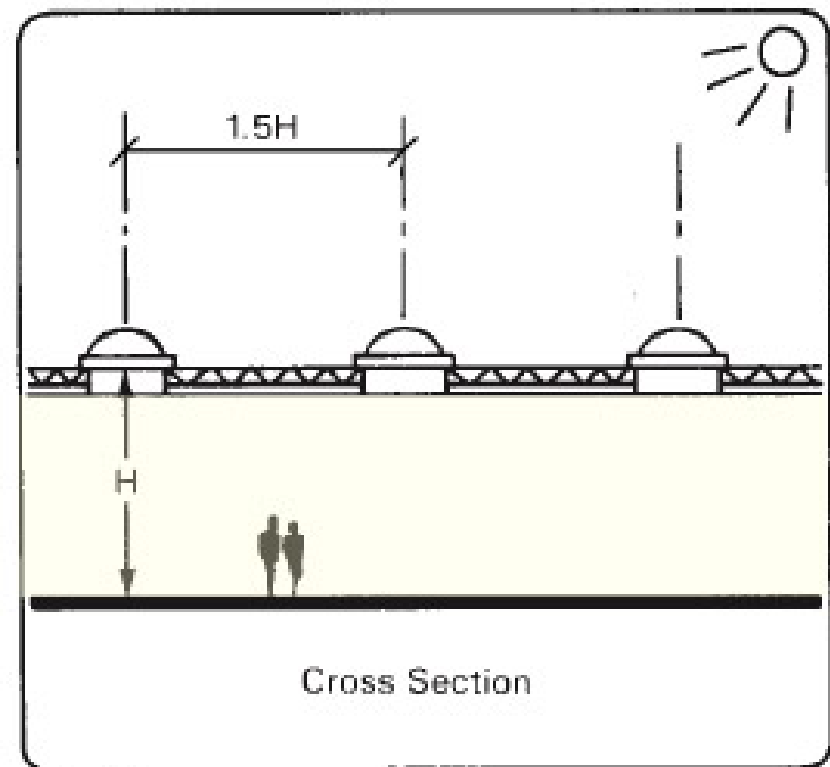


The ratio of skylight area to floor area is called the...

Skylight to Floor area Ratio (SFR)

# Unit Skylight Spacing Rules of Thumb

- The general rule of thumb is to space skylights at **1.0 to 1.5 times the ceiling height** (center-to-center in both directions)
  - Assuming a need for uniform diffused light throughout the space
  - Assuming an exposed ceiling
  - Actual designs can vary considerably based upon skylight type, light well depth and splays, and the presence of furniture or shelves in the space



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# So what is an optimum skylighting layout?

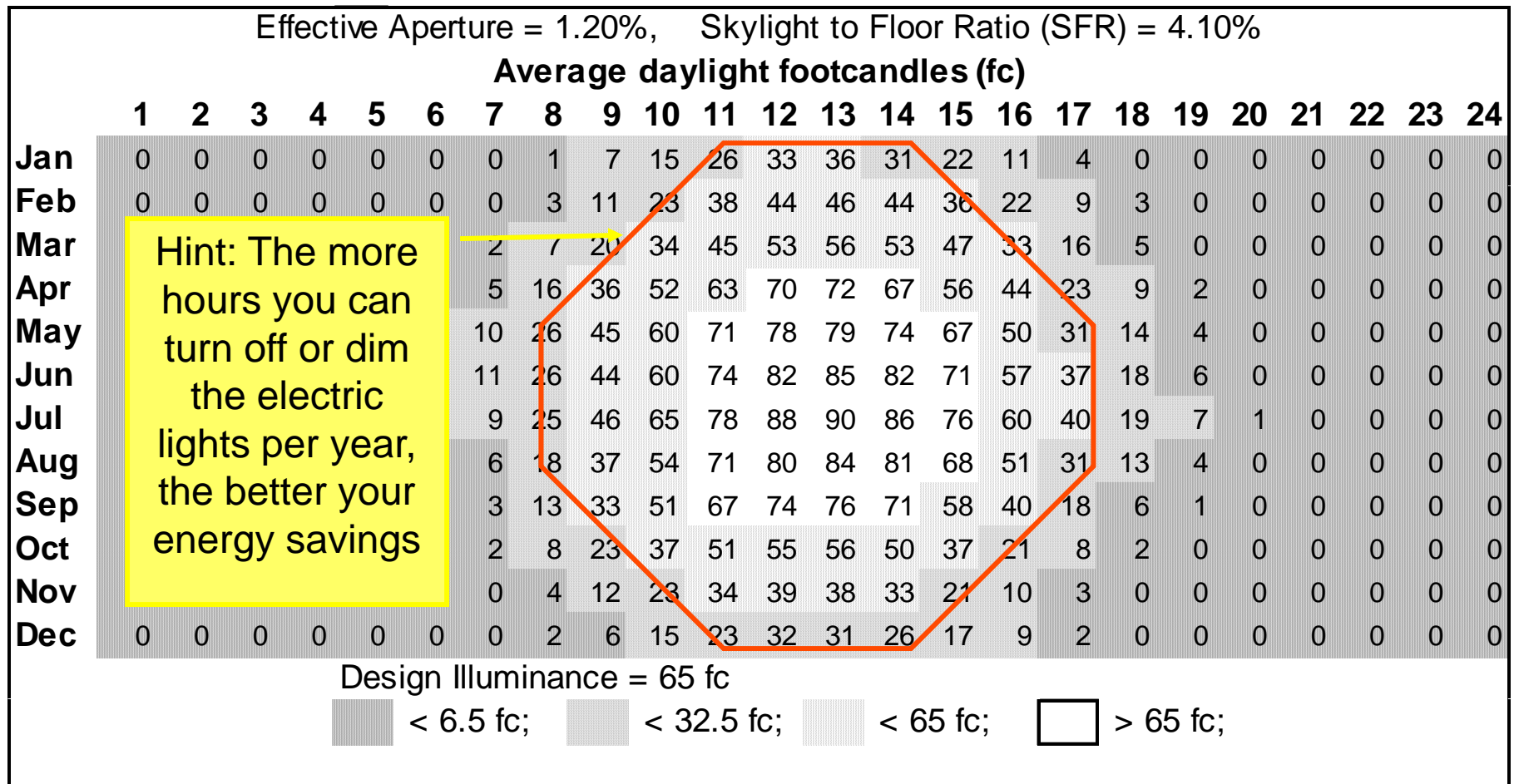
- The simple answer is...
  - **...it depends!**
  - What are your priorities?
- The optimum sizing and layout of a skylight system is dependent on many variables:
  - **Preferences for illumination levels** – Occupants often prefer higher illumination levels
  - **Uniformity** – Glazing properties, skylight spacing and room geometry determine uniformity of illumination levels
  - **Energy savings** - The best systems reduce electric lighting needs, while minimizing solar heat gains and nighttime heat losses
  - **Cost Savings** – Determined by the relative costs of heating fuels versus electricity
  - **Cost of installation** – Fewer unit skylights will cost less to install
  - **Code compliance** – Check with your local code enforcement agency to ensure code compliance

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# Optimizing Unit Skylighting Layout

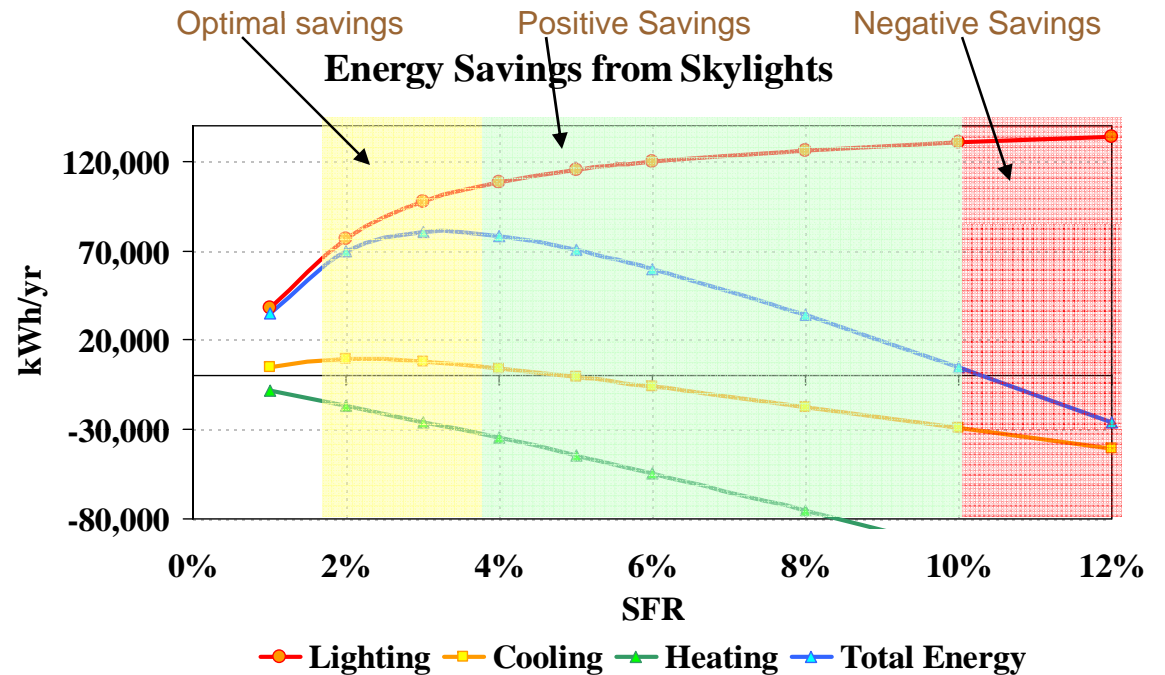
- Help is on hand to determine the optimal skylighting layout for your building!
- SkyCalc<sup>®</sup> is a Microsoft Excel<sup>®</sup> based application
  - It is a simple, free, publicly available tool that calculates energy impacts and illumination levels in a space for a given skylight and building design using typical hourly weather information for a nearby city
  - It also models interactive effects with other controls such as
    - Occupancy schedules
    - Photocontrol algorithms
    - HVAC interactions
- *See the 'additional resources' slide at the end of this module for how to receive a free copy*

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



# Well Designed Systems = Net Energy Savings

- More is not always better when it comes to skylights
- More skylights (bigger SFR) can provide ever greater lighting energy savings
  - But there is a limit!
- Beyond a certain SFR, increases in heating and cooling loads can outweigh lighting energy savings and thus increase the total energy use of the building
  - So choose your skylight area wisely!



The above diagram illustrates the energy savings information, as calculated by SkyCalc, for a particular building design in a particular climate

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# Why unit skylights can reduce cooling loads

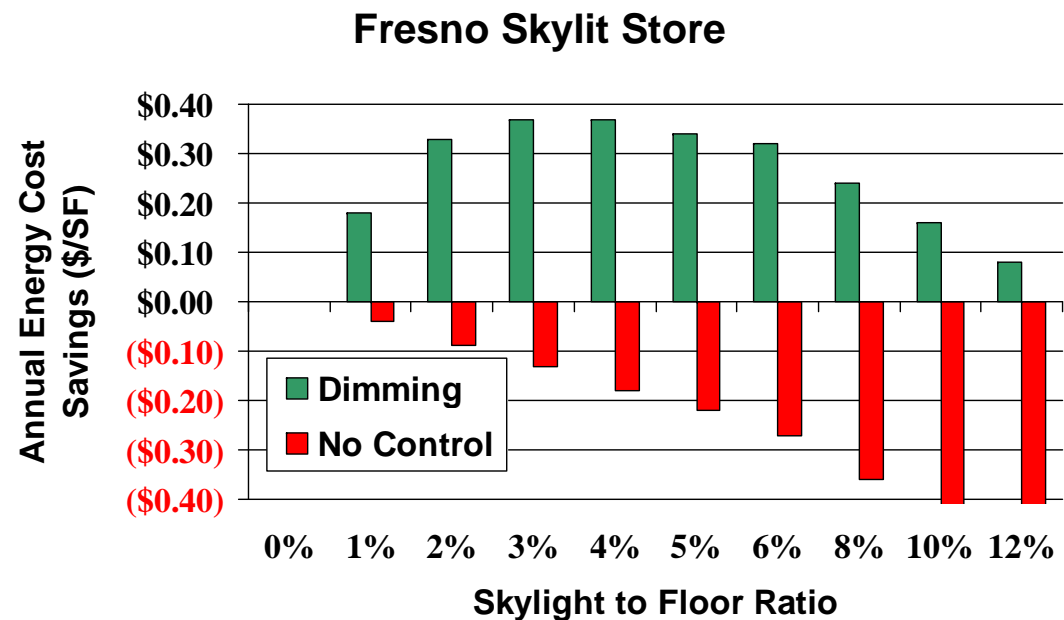
- Unit skylights save energy by reducing electric lighting usage
  - Daylight is inherently more efficient than electric light
    - It provides more lumens with less heat gain than any electric source
    - Thus, by using daylight to replace the electric lights, less heat is introduced into the space
    - The most important feature of a skylight is how much light it provides
  - Too much daylight will, however, result in excessive heat gain
    - So make sure the skylights are appropriately sized
    - And make sure the electric lights get turned off!
  - Unit skylights have the potential, if not carefully chosen, to increase heating loads in a building
    - Especially in the winter and at night
    - So make sure the HVAC equipment is sized appropriately

# Unit Skylight Energy Savings

- You may not save energy when the electric lights are not properly dimmed or switched in response to daylight!
- Automatic photocontrols guarantee the energy savings
  - lighting controls for electric lighting based on daylight availability

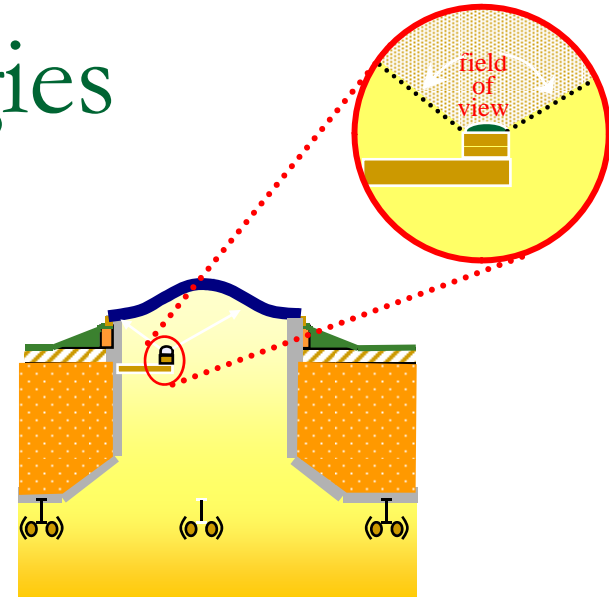
Example – A typical skylit store in Fresno, California where there is hot, sunny weather

- With functioning photocontrols, (green bars) the store saves energy and money
- But without photocontrols (red bars) skylights will actually increase the total energy use of the building

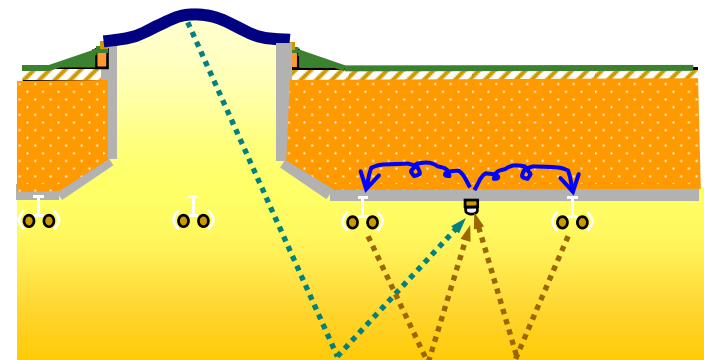


# Lighting Control Strategies

- There are two main control strategies
  - **Open loop controls**
    - The sensor responds to daylight illumination levels and reduces electrical lighting usage
    - The photosensor typically faces upwards looking out of the skylight or mounted on the outside of the building
  - **Closed loop controls**
    - The sensor responds to both daylight and electric light in the space
    - The photosensor is typically placed on the ceiling looking down upon the task area



Open Loop Controls



Closed Loop Controls

# There are many lighting control options...

## ❑ ON/OFF

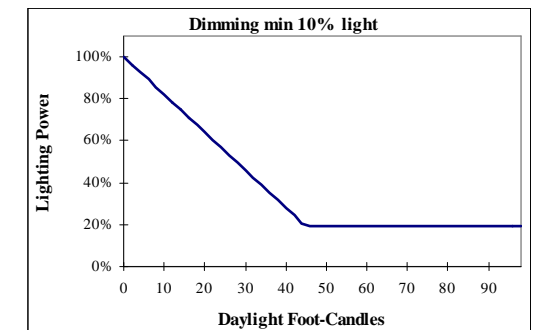
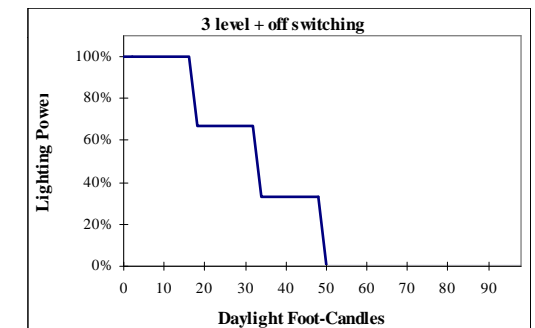
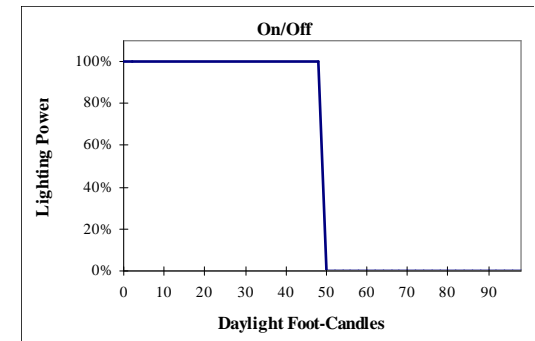
- This is the simplest form of control where all of the controlled lamps are turned OFF when there is adequate daylight

## ❑ Multi-level switching

- Individual lighting circuits, fixtures or lamps are controlled separately
  - ❑ Depending on task needs, light output can be reduced sequentially by one-third, half, two-thirds or completely

## ❑ Dimming

- All the controlled lamps are dimmed with the help of dimmable ballasts to achieve lower light output and energy consumption
  - ❑ Dimming provides the best quality light control
  - ❑ It is also the most expensive and does not always save the most energy!
- ❑ Learn more about lighting controls with the references listed at the end of this course



# How well do the photocontrols really work?

- **Very well! Especially in skylit applications!**

- A recent study conducted in Southern California<sup>1</sup> showed that
  - On average, they saved 97% of their predicted savings

- Some of the other urban myths around photocontrols operation were also debunked:

- **The photocontrols performed very well**

- None of the systems physically failed

- **Users were generally happy with their performance**

- No one taped over a photosensor
- No one clipped control wiring
- Some users saved even more energy than predicted by using manual overrides to turn the lights off for more time of the day

- **But savings depend on the control equipment being commissioned correctly**

- Those systems that did not work at the opening of the building, never worked

1. [Check additional resources slide for the SCE Photocontrols Effectiveness Study](#)



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# Skylights and Energy Codes

- **California's Title 24** requires skylights and photocontrols in single story buildings 25,000 square feet or larger
  - Such as warehouses and big box retail stores
  - See the new 2005 CA Title 24 Compliance Manual for further details
- **ASHRAE/IESNA 90.1-2006** limits skylight area to 5%
  - Glazing must have a 90% minimum haze factor
  - The visible light transmittance (VLT) must be greater than 0.40
  - Or with Energy Cost Budget (ECB) Method any area can be used
    - as long as the building uses less energy than 5% SFR
- **International Energy Conservation Code (IECC) 2003**
  - IECC recognizes ASHRAE/IESNA 90.1

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# Skylights also need to meet various criteria

- Building Codes
- Safety Standards
- Rating Standards

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# Additional Resources

Now that we have given a brief overview of the skylighting design issues and specifications, you are ready for more detailed information

1. The **AAMA Web site** is a great resource for skylight specifications and manufacturer information. It also has a sortable product finder.
  - Visit [www.aamanet.org](http://www.aamanet.org)
2. The **Skylighting Guidelines** has detailed information on skylighting design issues that we have introduced in this module.
  - Download guidelines at <http://www.energydesignresources.com>
3. Skylights in spaces with suspended ceiling present unique challenges. The **Modular Skylighting Guidelines** are a great design and specification guide. You can download the guidelines at
  - [www.h-m-g.com/projects/skylighting/main.htm](http://www.h-m-g.com/projects/skylighting/main.htm)

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# Additional Resources

4. Download **SkyCalc™** at
  - [www.energydesignresources.com](http://www.energydesignresources.com) or [www.h-m-g.com](http://www.h-m-g.com)
5. The **Advanced Lighting Guidelines** are an excellent reference on lighting quality and design issues.
  - <http://www.newbuildings.org/lighting.htm#guide>
6. The **Photocontrols Effectiveness Study and Installation Guidelines** have excellent data on photocontrol system operation in the field and guidelines for proper commissioning.
  - [http://www.calcodesgroup.com/database/download/CalCodes\\_Report\\_48.pdf](http://www.calcodesgroup.com/database/download/CalCodes_Report_48.pdf)

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# Required Reading Materials

1. Lighting **knowhow™ Series Design Guides** from the Design Lights Consortium have case studies and sample design layouts for skylighting in retail and warehouse buildings
  - Download at <http://www.designlights.org/skylighting.html>
  - *The knowhow™ series design guides on warehouse and retail skylighting are required reading materials and have been provided courtesy the DesignLights™ Consortium (DLC), an initiative of the Northeast Energy Efficiency Partnership (NEEP).*

# End of Module!

- So now that you have completed reviewing the *Introduction to Skylighting* Module
- Are you ready for the quiz? Use the link emailed to you to access the quiz
- Upon an 80% accuracy rate on the quiz, your credits will be processed with the AIA
- Thanks for your interest in skylights and skylighting design
- Good luck with your future daylighting endeavors!



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# Introduction to Unit Skylights for Daylighting of Commercial Buildings

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*An evaluation form will be sent to you via an emailed link, please take a moment to offer your feedback.*

*Please [click here](#) to request a subscription to the Skylight Council Newsletter to stay apprised of activities and developments in the skylight industry.*