



# Day lighting

## ENERGY STAR Monthly Partner Web Conference

**June 21, 2006**

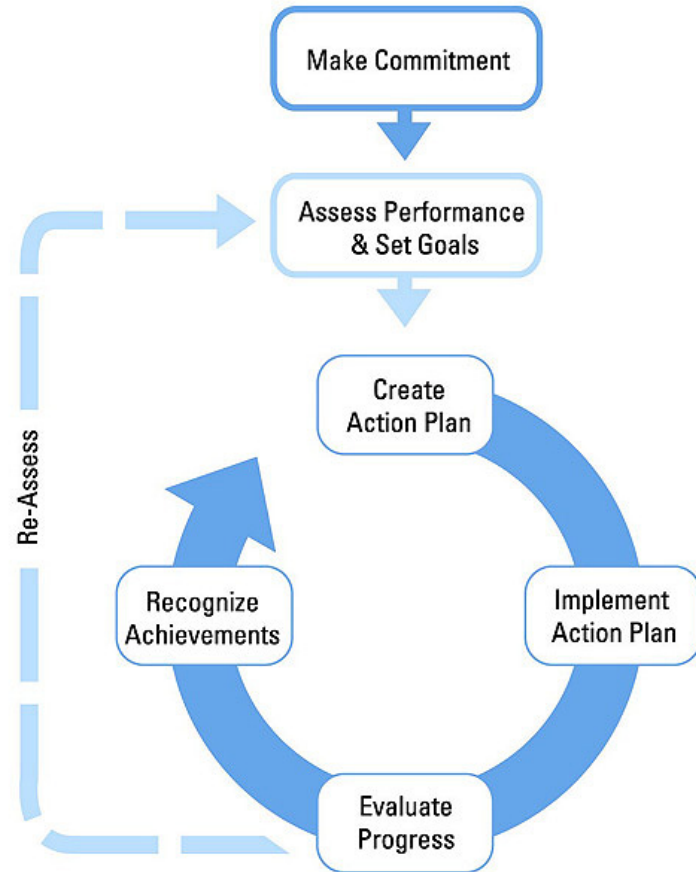
Call-in Number: 1-866-299-3188

Conference Code: 202 343 9965

# About The Web Conferences



- **Monthly**
- **Topics are structured on a strategic approach to energy management**
- **Opportunity to share ideas with others**
- **Slides are a starting point for discussion**
- **Open & Interactive**
- **Supports the ENERGY STAR Challenge to build a better world, 10% at time**



# Web Conference Tips

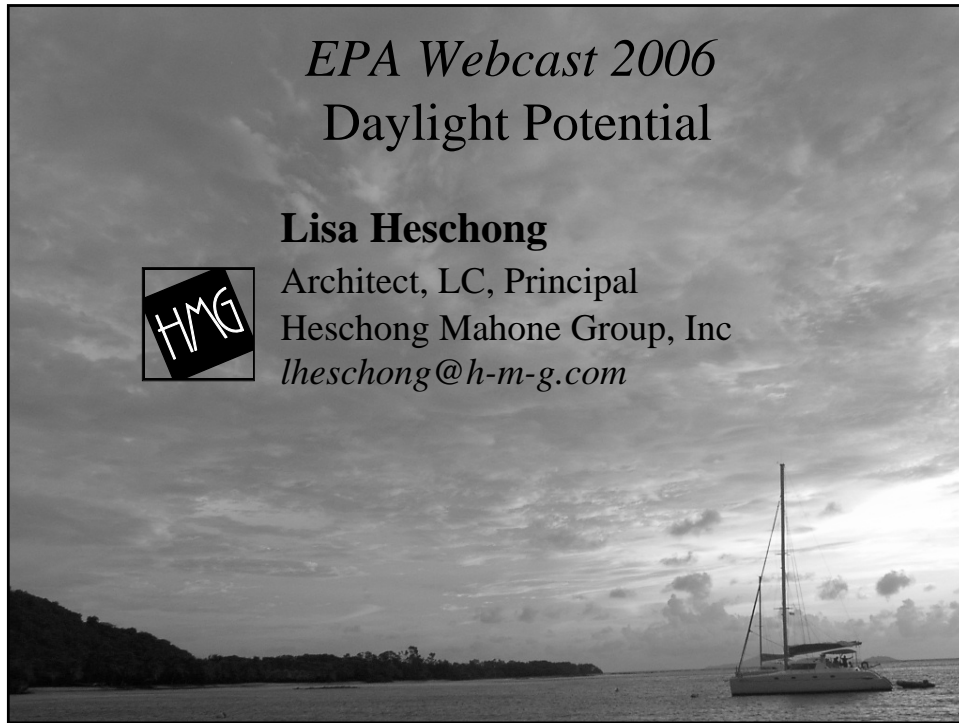


- Mute phone when listening! Improves sound quality for everyone.  
Use \* 6 – to mute and # 6 to un-mute
- Hold & Music – If your phone system has music-on-hold, please don't put the web conference on hold!
- Presentation slides will be sent by email to all participants following the web conference.

# Today's Web Conference

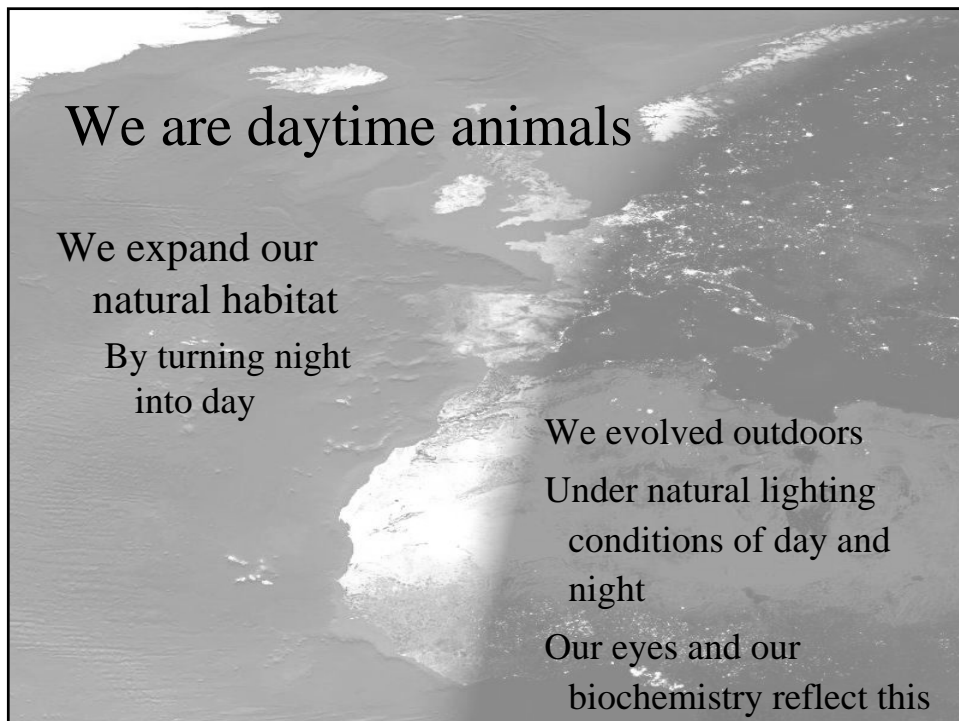



- Welcome



*EPA Webcast 2006*  
**Daylight Potential**

**Lisa Heschong**  
Architect, LC, Principal  
Heschong Mahone Group, Inc  
*lheschong@h-m-g.com*



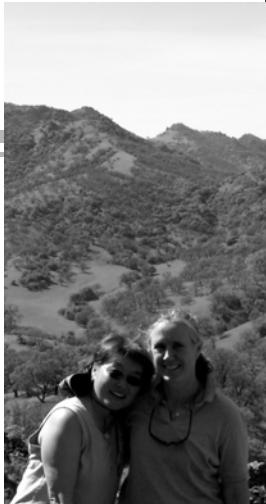
**We are daytime animals**

We expand our  
natural habitat  
By turning night  
into day

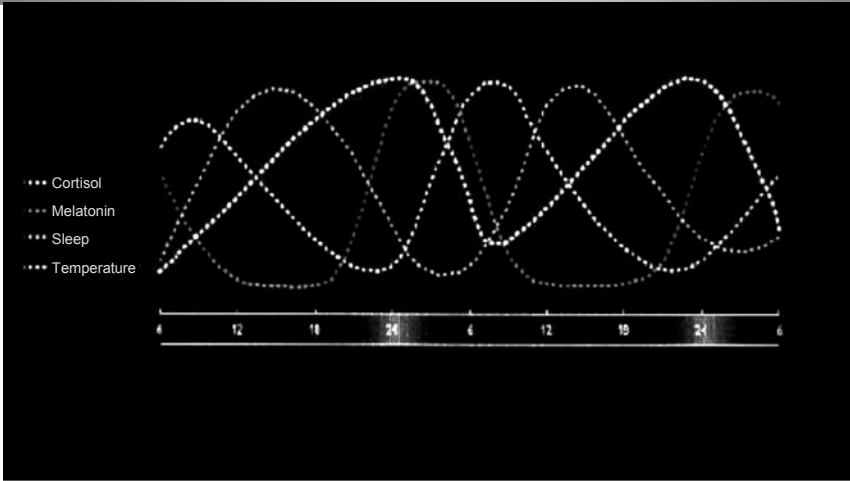
We evolved outdoors  
Under natural lighting  
conditions of day and  
night  
Our eyes and our  
biochemistry reflect this


## Circadian Health

- Circadian cycles are more comprehensive than we thought.....
  - Alertness / sleep cycles
  - Growth / development cycles
  - Neurological function
  - Immunological function
- Patterns of LIGHT and DARKNESS are key to “entrainment”
  - Like a two cylinder engine, a push – pull pattern



## Synchronizing Daily Rhythms





## Neurotransmitters

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**Turned on by DARK**

- Melatonin – sleep, mood, puberty,
- Norepinephrine – mood, intelligence, insulin resistance
- Acetylcholine – learning, memory

**Turned on by LIGHT**

- Serotonin – impulse control, carbohydrate cravings
- Dopamine – motivation, muscle coordination
- GABA (Gamma-Aminobutyric Acid) – calm, focus, inhibition

“Light is a Drug” Dr. George Brainard



## Hormones and Peptides

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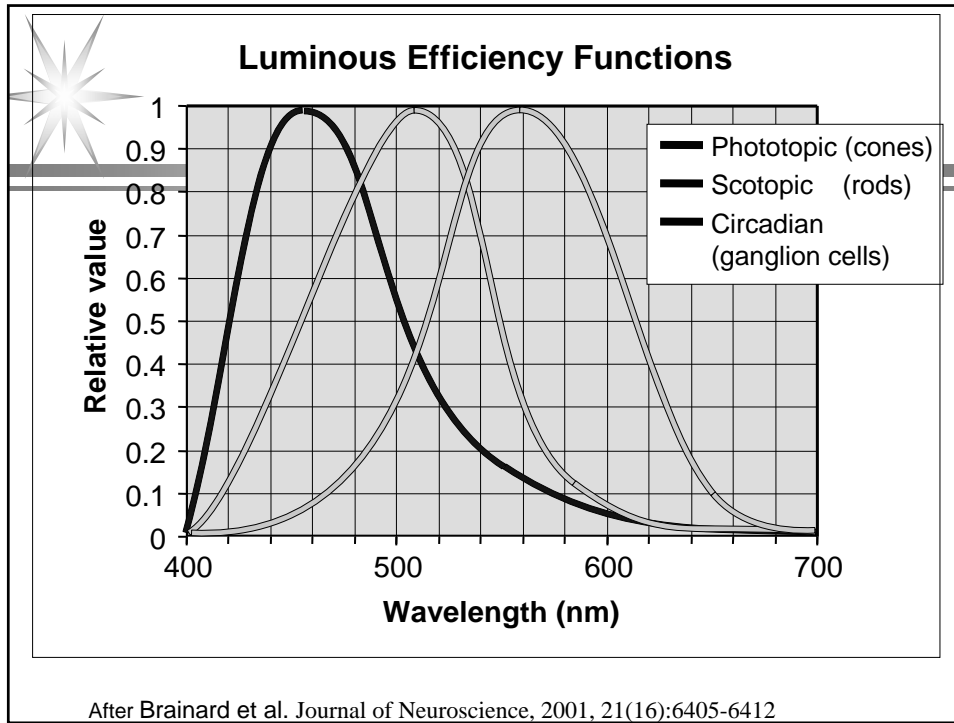
**Turned on by DARK**

VIP	Vasoactive Intestinal Peptide	Blood pressure
GH	Growth Hormone	Growth, in children
		adults: decrease body fat, increase lean muscles

**Turned on by LIGHT**

CRF	Corticotropin Releasing Hormone	Stress
GRP	Gastrin Releasing Peptide	Hunger
NPY	Neuropeptide Y	Hunger
FSH	Follicle Stimulating Hormone	Reproduction

After: Dr. Joan Roberts



### Circadian Effectiveness

Is a function of the overlap between:

- the spectral power distribution of the light source, and
- the sensitivity of the circadian system

Our retinas include non-visual “blue sky detectors”

**Noontime Sunlight**


**Incandescent**

**Tri-phosphor fluorescent**

RELATIVE POWER


WAVELENGTH (nanometers)




 **Before Electric Lighting....**

**Daylight used to determine our work patterns**

**All buildings were daylit**




 **The age of fluorescent lighting**

Invented in the 1930's

Low cost allowed:

- Night shift work
- Buildings without windows





Buildings are cheaper  
without windows  
Deeper “plates”  
Fewer walls

Windows create  
“distractions” for  
children & workers  
And maintenance problems  
And HVAC challenges

Electric lighting and  
mechanical ventilation can be engineered  
to maintain the “ideal” (static) environment....24/7

*And we may all die of boredom....*





## Daylight & Productivity: 8 Major Field Studies

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All downloadable from [www.h-m-g.com](http://www.h-m-g.com)

**Retail**  
Two major chain stores      108 and 74 stores, sales data  
Retailer A: +40% sales, w skylights, all other things equal  
Retailer B: +1% - +6% average sales, up to +40% in best case

**Schools**  
Four school districts    8-9000 students each, math and reading test scores  
+21% faster learning with more windows or skylights  
+7% to +30% faster learning with better window views

**Offices**  
“Call Center”      100 subjects, 2 months, work speed  
+7% faster with better window views  
7% increases in efficiency = \$118/sf\*yr, or cost of construction  
“Desk Top” 200 subjects,  
+20% better cognitive performance w more daylight  
Better memory, fewer health complaints w better views

We swim  
in a sea of  
daylight  
every day...

Shouldn't  
we design  
our buildings  
to let it in?



## What is the magic?

### Excellent illumination

- Gentle ambient light
- Excellent color
- Highlights & shadows
- Meaningful variation

### Healthier environments


- Fewer occupant complaints
- Mental & emotional engagement

### Sustainable

- Lower energy use
- Lower peak demands
- 50+ year life



Photos © Heschong Mahone Group




25% to 40 % of building area


## Why Skylights?

Where is there most surface area?

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50% to 95 % of building area

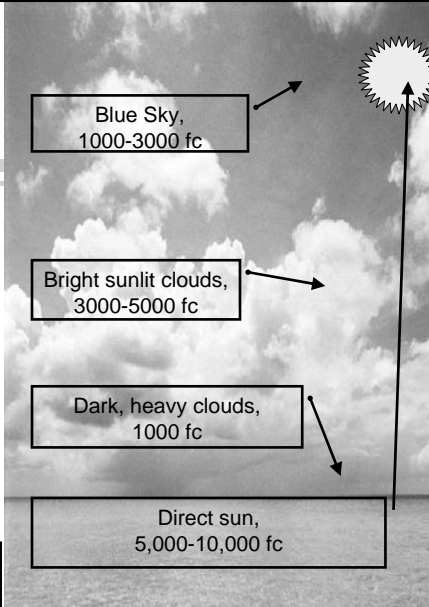


## How much light?

Windows provide daylight from part of the sky  
They must be shaded from the sun

Skylights can use both sunlight and daylight from all of the sky  
Diffuse sunlight, spread it evenly  
Like a sprinkler head on a hose...

3x more light/sf on an overcast day  
10x more light/sf on a sunny day


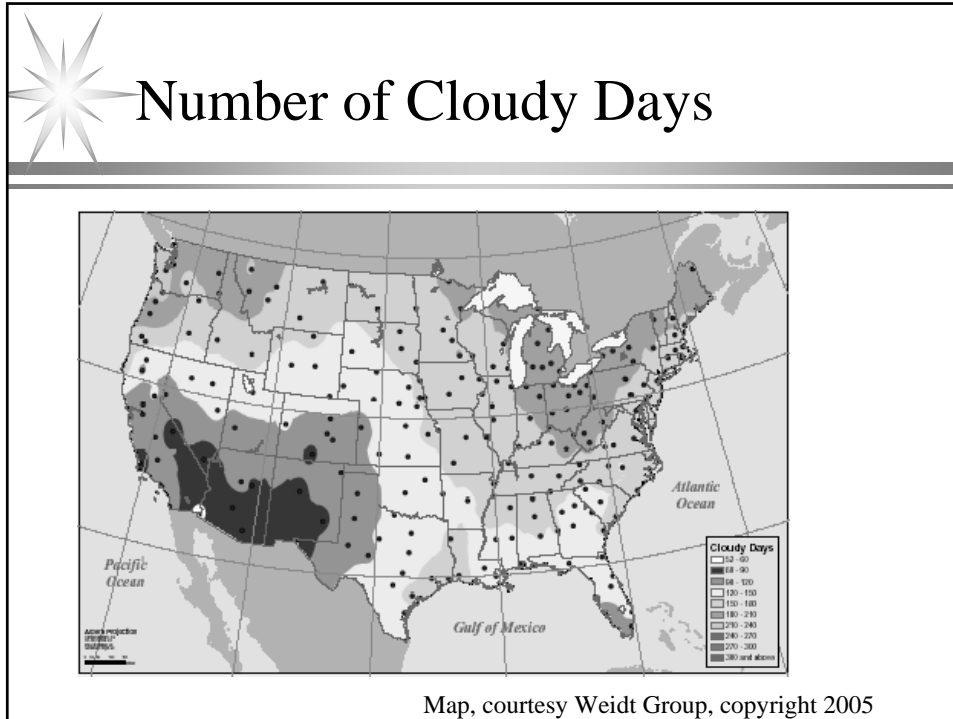


Blue Sky, 1000-3000 fc

Bright sunlit clouds, 3000-5000 fc

Dark, heavy clouds, 1000 fc

Direct sun, 5,000-10,000 fc



## Energy Savings with Daylighting

30% to 80%	lighting energy savings
5% to 50%	whole-building energy savings
10% to 20%	reduction in peak electricity use

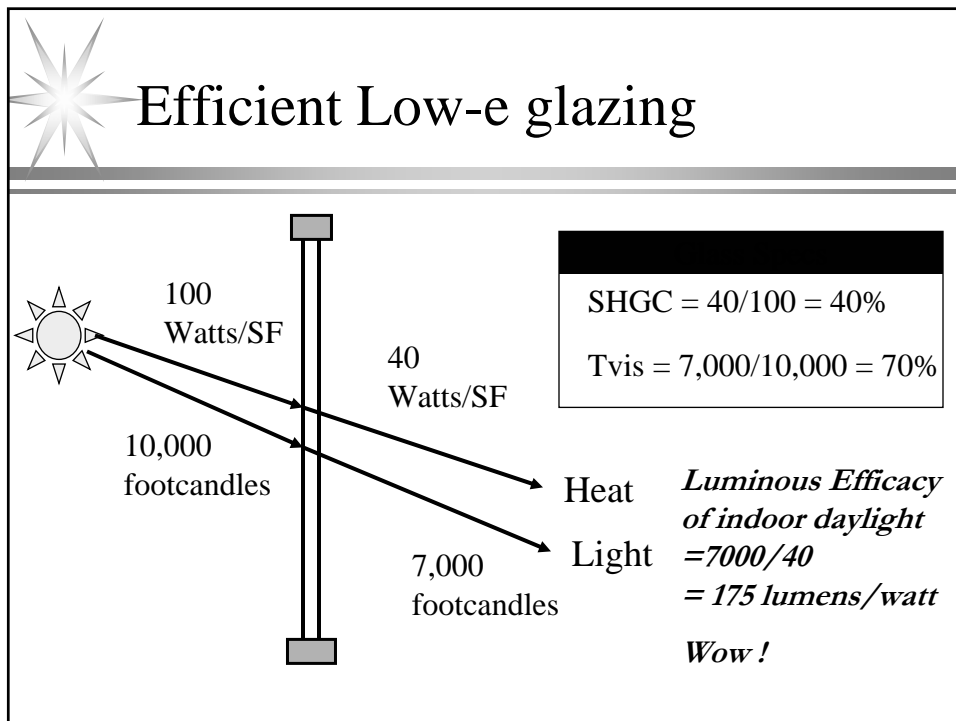
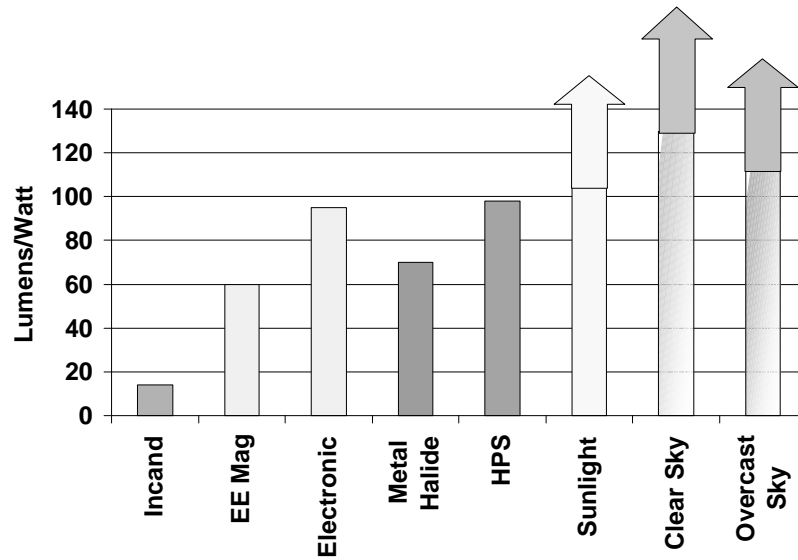
And, it works for the life of the building...

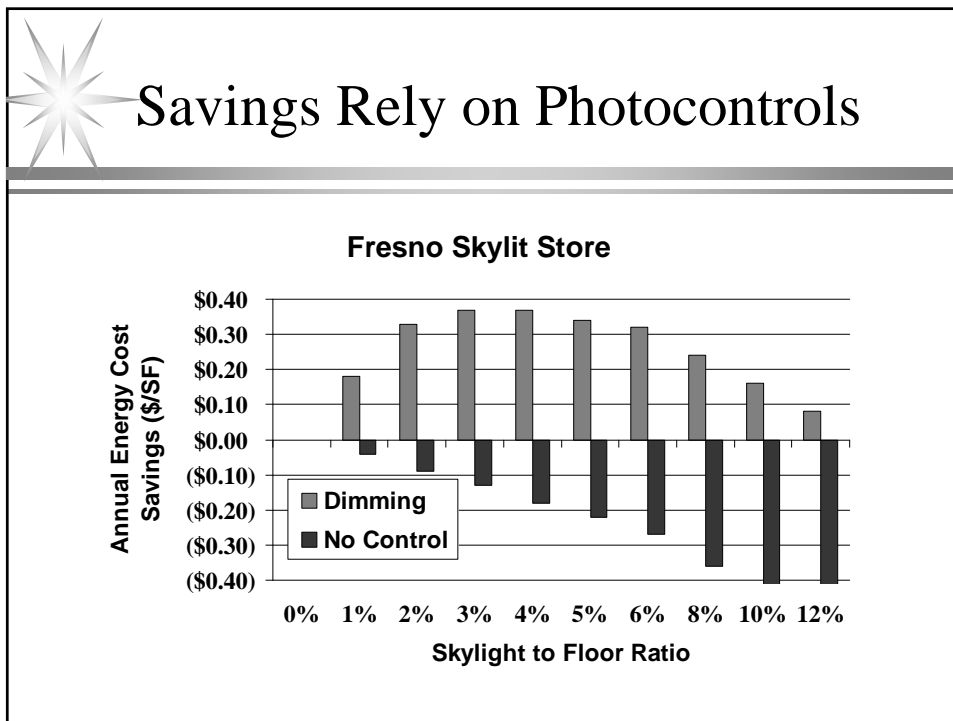
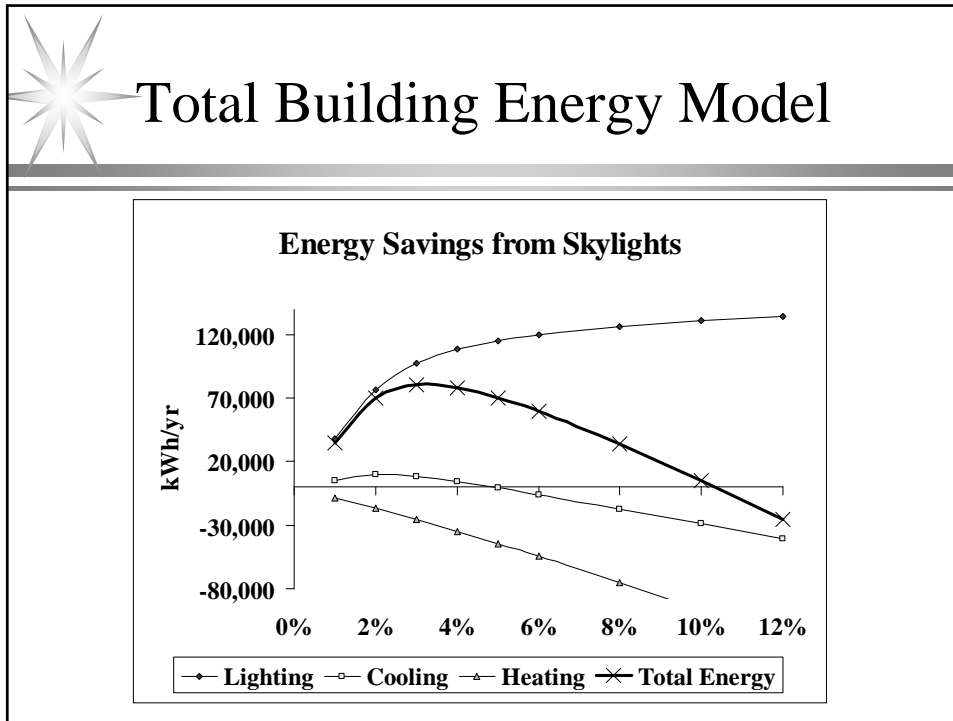
And, it works even when the power goes out !


Important for hospitals, schools, nursing homes...

*Escalators are never broken....they just turn into stairs....*

## The secret: Light, not Heat








## Photocontrols – field performance

<p><b>Top-lighting</b></p> <ul style="list-style-type: none"> <li>Working 96% of time</li> <li>Saving 98% of predicted</li> <li>Highly persistent</li> </ul> <p><b>Savings potential</b></p> <ul style="list-style-type: none"> <li>1.5 kWh/sf*yr</li> <li>1.0 W/sf peak reduction</li> <li>For controlled zone</li> </ul>	<p><b>Side-lighting</b></p> <ul style="list-style-type: none"> <li>Working 50% of time</li> <li>Saving 50% of predicted kWh</li> <li>Highly persistent</li> <li>(once working)</li> </ul> <p><b>Savings potential</b></p> <ul style="list-style-type: none"> <li>1.1 kWh/sf*yr</li> <li>0.6 W/sf peak reduction</li> <li>For controlled zone</li> </ul>
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## Skylight Illumination - Yearly Pattern

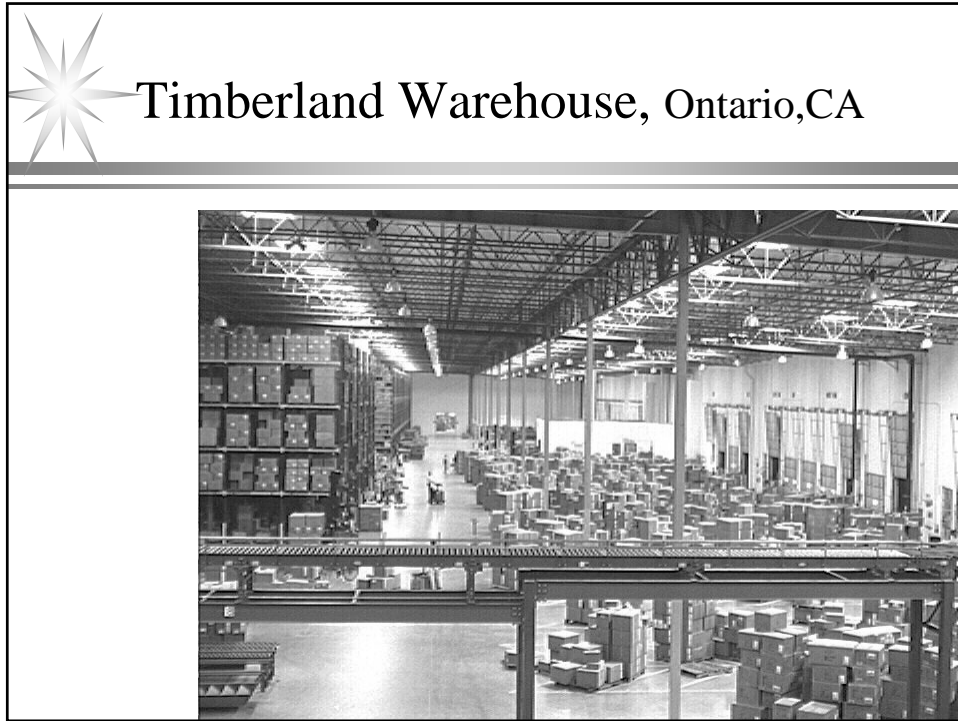
Effective Aperture = 2.50%, Skylight to Floor Ratio (SFR) = 5.00%

	Average daylight foot-candles																								
	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	2	8	15	32	42	45	39	27	14	5	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	2	14	29	47	55	57	50	45	27	11	3	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	2	9	25	42	57	66	70	67	58	41	20	6	0	0	0	0	0	0	0
Apr	0	0	0	0	0	1	6	20	45	65	79	88	90	84	70	55	29	11	3	0	0	0	0	0	0
May	0	0	0	0	0	3	12	33	56	75	89	98	99	93	85	63	39	17	5	0	0	0	0	0	0
Jun	0	0	0	0	0	4	14	32	55	75	93	103	107	102	89	71	46	22	8	0	0	0	0	0	0
Jul	0	0	0	0	0	3	11	31	57	81	98	110	113	108	95	75	50	23	9	1	0	0	0	0	0
Aug	0	0	0	0	0	1	8	22	46	68	90	101	105	101	85	61	39	16	5	0	0	0	0	0	0
Sep	0	0	0	0	0	0	1	17	41	64	84	93	96	88	72	50	23	8	1	0	0	0	0	0	0
Oct	0	0	0	0	0	0	2	10	29	46	64	69	71	62	47	26	10	2	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	5	15	29	42	48	48	42	26	12	4	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	2	8	18	30	40	39	33	22	11	3	0	0	0	0	0	0	0	0


Design Illuminance = 50 fc  
 < 5 fc;   
  < 25 fc;   
  < 50 fc;   
  > 50 fc;

Monthly averages plotted (+/- 30%)  
 Energy savings are at the margins...1 hr more in am & pm....













## Goals for Daylight Design

- Provide visual quality**
  - Adequate ambient illumination
  - Prevent glare sources
  - Visual interest
    - with dynamic variety – shades and sparkle
- Save energy**
  - Turn off unnecessary electric lights
  - Avoid thermal discomfort, negative HVAC impacts
- Provide circadian and mental stimulation**
  - More daylight illumination – at the eye
  - Provide access to “relaxing, interesting,” outside views
  - Promote interesting luminance variation, in time and space
- Create aesthetically pleasing spaces**






## Daylight – disabled



First comes the sunlight  
Then the shades...  
Then the glare...  
Then come the disabled controls...



## Daylight Solutions

**Basic Good Daylight Design**

- Orientation
- Shading
- Glare control (allowing occupant adjustment !)

**Dynamic Controls – the Daylight Frontier**

- Windows with auto-controls
  - For more daylight, less glare, less solar heat
- Skylights with auto-controls
  - Louvers or electro-chromic glazing—reduce heat loss, excessive light
- Light-redirecting materials
  - Integral blinds, tubular skylights, sun-tunnels, laser cut panels

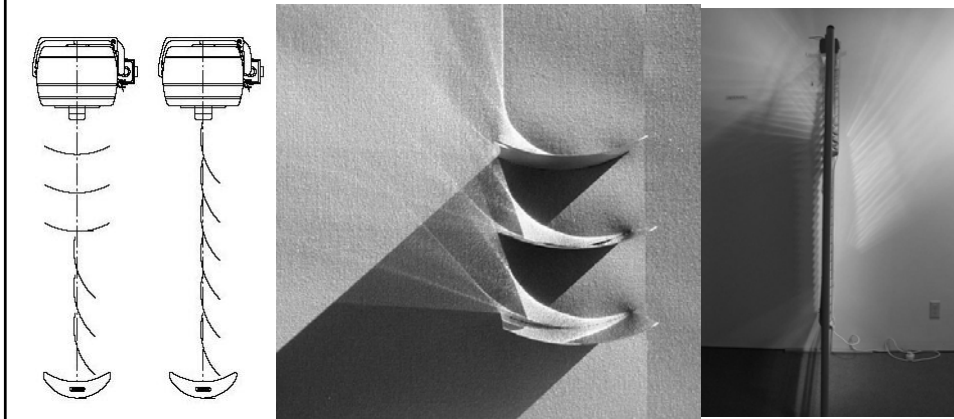
### Automated, daylight-optimized blinds

Inverted to redirect daylight upwards

Perforated for view

Separate controls, for view v daylight portions

Specular for solar control



## Resources

[www.energydesignresources.com](http://www.energydesignresources.com)

Skylighting Guidelines, Design Briefs, tutorials, case studies  
SkyCalc, eQuest,

[www.betterbricks.org](http://www.betterbricks.org)

Daylighting discussions, case studies

[www.iesna.org](http://www.iesna.org)

Advanced Lighting Guidelines

[www.chps.net](http://www.chps.net)

Best Practices Manual (for K-12 schools)

[www.h-m-g.com](http://www.h-m-g.com)

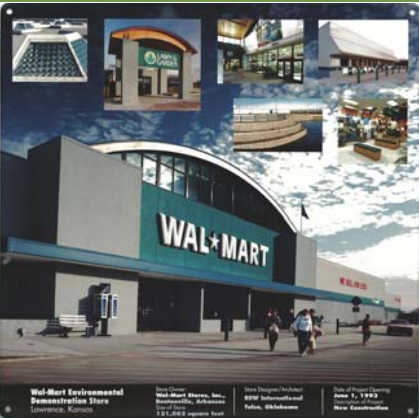
Daylighting research studies



**The past, present and  
future of Daylight  
Harvesting at Wal-Mart**

# Wal-Mart Daylight Harvesting

## History of Daylighting at Wal-Mart



### Lawrence, KS Environmental Demonstration Store-Spring 1993

Half with Suspended Continuous Dimming Fluorescent Lights and Skylights

Half without Skylights

Tested Six Anderson First Generation “Lighthouse” skylights

### City of Industry, CA Environmental Demonstration Store-Fall 1995

Partnered with SCE and CEC

Designed with no ceiling and added 174 Skylights

First Full Daylight and Light Dimming Tests

Dozen Anderson Second Generation “Lighthouse” skylights

Passive Dome Bristolite (fiberglass) Skylights-main sales

Active (Solar Tracking) First Generation Soluminare Skylight Test

First Full Scale Low Mercury Lamp Tests (Philips ALTO)

Excellent Appearance and Acceptance



# Wal-Mart Daylight Harvesting

# Skylight Tests and Evaluation



First generation of Anderson "Lighthouse"  
skylight used in Lawrence, KS

Second generation Anderson "Lighthouse"  
skylight used in City of Industry, CA





# Wal-Mart Daylight Harvesting

# Skylight Tests and Evaluation



First version of a solar tracking skylight test and evaluation in City of Industry, CA-1993

Current version of a solar tracking skylight test and evaluation in Aurora, CO-2006



# History of Daylighting at Wal-Mart

## **Moore, OK Environmental Demonstration Store-Fall 1995**

First Supercenter-Partnered with OG&E and EPRI

Bi-Level Metal Halide with 265 Skylights over Sales, Stockroom and TLE

HID Dimming was difficult to control and maintain

Interior Column Mounted Closed Loop Sensor for Control

Excellent Acceptance

## **Port Charlotte, FL Supercenter-Early 1996**

Changed to first Continuous Dimming Fluorescent Lighting

Designed with approximately 220 Skylights over Sales, Stockroom and TLE

Interior Column Mounted Closed Loop Sensor for Control

“Standard” Design for 10 Years

# Wal-Mart Daylight Harvesting

## Curb Specifications-Safety

### Fixed and Venting Skylight Curbs

Safety Screen: Shop fabricated 3/16 inch cold rolled galvanized steel rods welded in 6 inch by 6 inch grid pattern. Attach to curb as shown. For venting skylights when used, allow room at top inside face of curb for smoke vent installation. Screen shall have been tested to withstand impact of 245 pound lead weight, 10-3/4 inch diameter, dropped from height of 3 feet and support concentrated load of 600 pounds after impact





# Wal-Mart Daylight Harvesting

## Skylight Specifications-Safety

### Safety Testing

- The ICBO approved test laboratory shall also perform a 200 lb drop test from a height of 24" above the center (highest point) of dome shape and at mid points of both the 5' and 6' side. (approximately 15" and 18" from center) The 200 lb. load shall be contained within a flexible bladder or sack having approximate dimensions no larger than 30" long, 20" wide, and 8" high, filled with course sand or pea gravel. The dome shall withstand the sack drop test without inverting. The drop test shall be witnessed and certified by the test laboratory which provides the ICBO Evaluation Report.

- Skylights shall be designed to carry a minimum 20 psf tributary roof load or greater per site as specified in the current International Building Code or prevailing model code.



# Wal-Mart Daylight Harvesting

## Skylight Specifications - Glazing

### Clear Glazing Panels

- Outer Lens: 50% minimum impact modified clear acrylic or clear prismatic acrylic of sufficient thickness to meet the ICBO uniform load and the 200 lb. drop test.
- Inner lens: High diffusing white prismatic acrylic.
- Energy Requirements: Glazing material shall have a maximum light distribution characteristic that maximizes the shading factor. The combined inner/outer lens target values shall be as follows:
  - Light Transmittance: 60 percent minimum.
  - Shading Coefficient: 0.60 maximum.
  - “U” Value: 0.42 or lower (glazing only).



# Maintenance - Ballast/Lamp Compatibility

## Situation

- Wal\*Mart is one of the largest users of T8 fluorescent dimming systems in the country.
- Beginning in 2004, Wal\*Mart has had excessive failures with F32T8 lamps used in dimming applications in its stores.
- Analysis of failures showed industry disparity between cathode heating voltage applied in dimmed mode versus cathode heating voltage required to maintain lamp life in dimmed mode. No specification for this parameter exists in the industry.
- **NEMA** member companies initiated a dimming task force to understand the issue and write a standard.
- Dimming Life Study at the **Lighting Research Center** in NY to provide pertinent data for the new specification.

## NEMA

## Fluorescent Dimming Task Force

Objective: Leverage **NEMA's** collective leadership to...

- Avoid setback to emerging energy management controls market opportunity
- Reduce reliability risk in dimming systems
- Parallel **LRC** work with best practices white paper, followed by interim **NEMA** standard as **DOE** experiment is completed. **ANSI** standard to follow.
- Manage risk to industry
  - drive buy-in behaviors ahead of standardization
  - interim standard assumes some risk level to lamp and ballast
  - refinement will minimize risk when long term data is available

# Maintenance Ballast/Lamp Compatibility

## Dimming and Life Study at LRC

### Objective

- Determine how different amounts of electrode heating voltage affect lamp life under dimmed operation
  - Linear, T8 32W lamps
- Develop recommendations for a dimming standard involving lamp, ballast and/or system specifications

### Scope

- Multiple ballast manufacturers, multiple lamp manufacturers
- Include major 32W T8 lamps with different cathode designs
- Consider two major factors that impact lamp life: cathode heating voltage, lamp current
- Continuous operation only (minimal cycling)



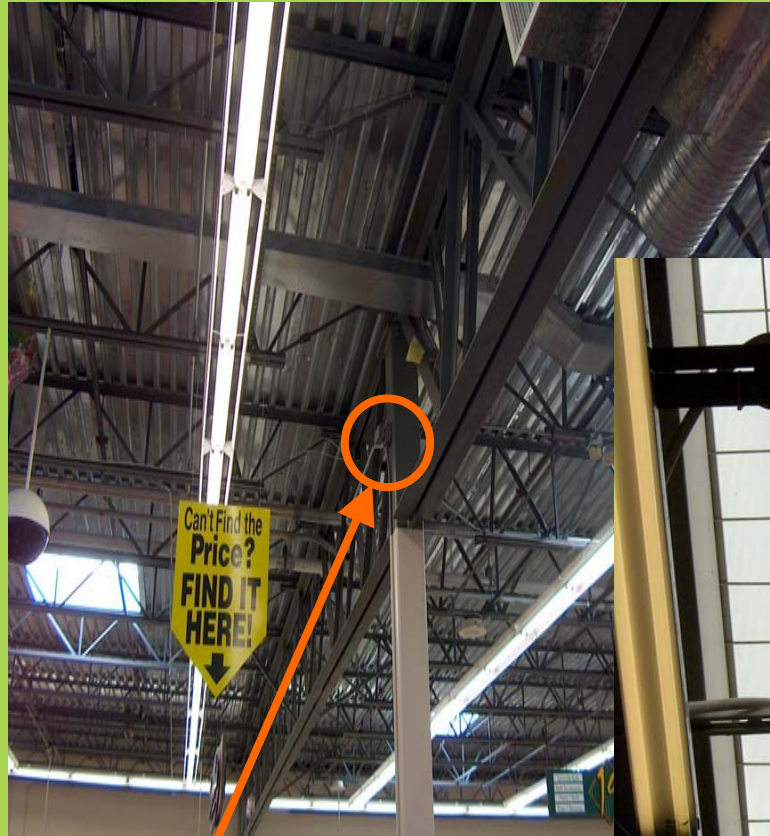
# Wal-Mart Daylight Harvesting

## Dimming Control Optimization

### IMPROVED DAYLIGHT CONTROL - 2005

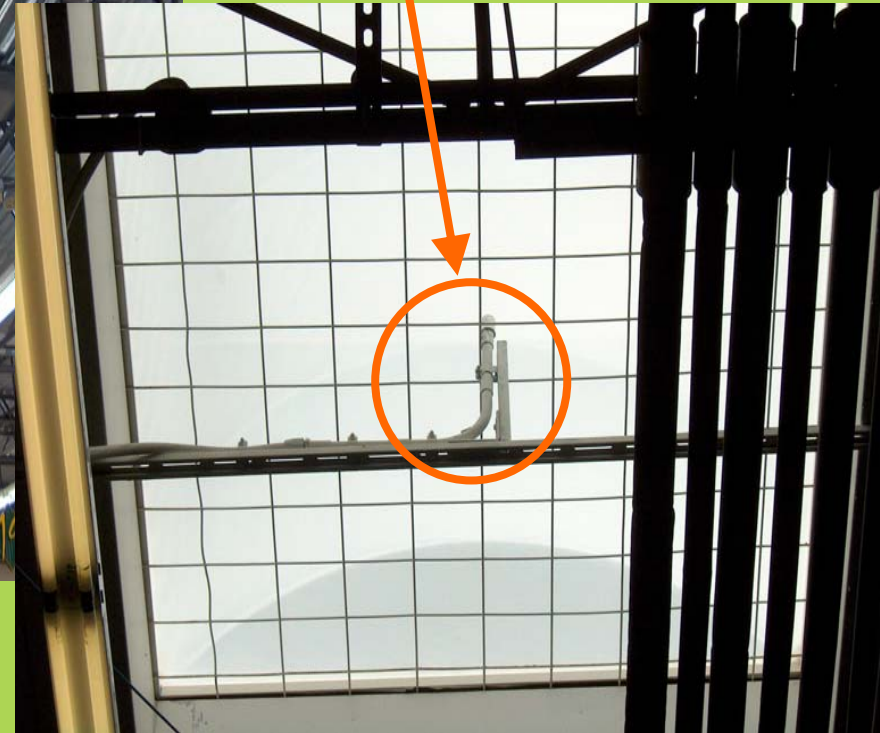
Use Skylight Mounted Open  
Loop Analog Light Sensor

Use Dimming Signal Feedback  
for Better Control (Set Limits)



**Interior daylighting  
sensor (closed loop)**

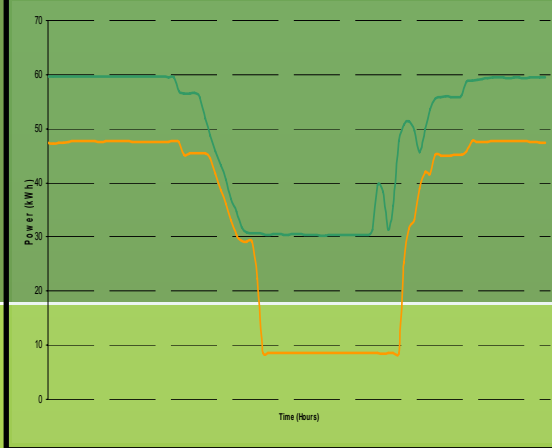
**Skylight sensor  
(open loop)**



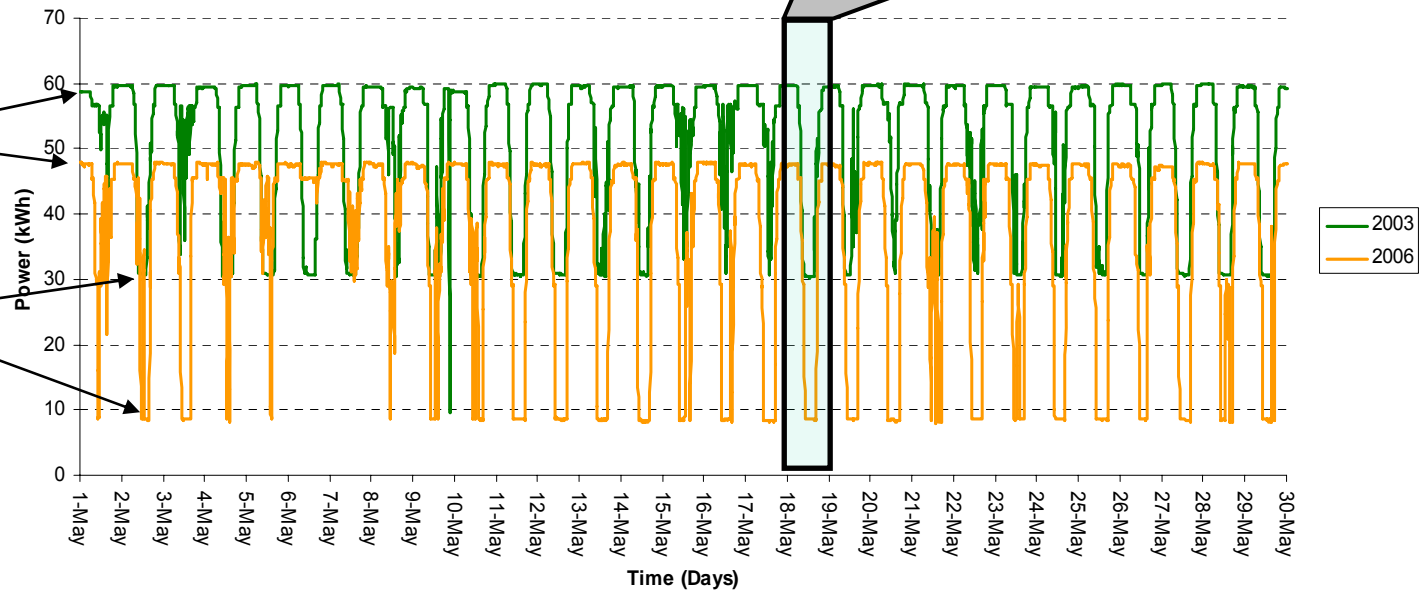


# Wal-Mart Daylight Harvesting

# Dimming Optimization



### Store 622 Dimming Optimization



Energy Saving from  
night dimming after  
optimization

Energy savings from  
ballast being switched  
off when light level in  
the store is bright  
enough

# Wal-Mart Daylight Harvesting

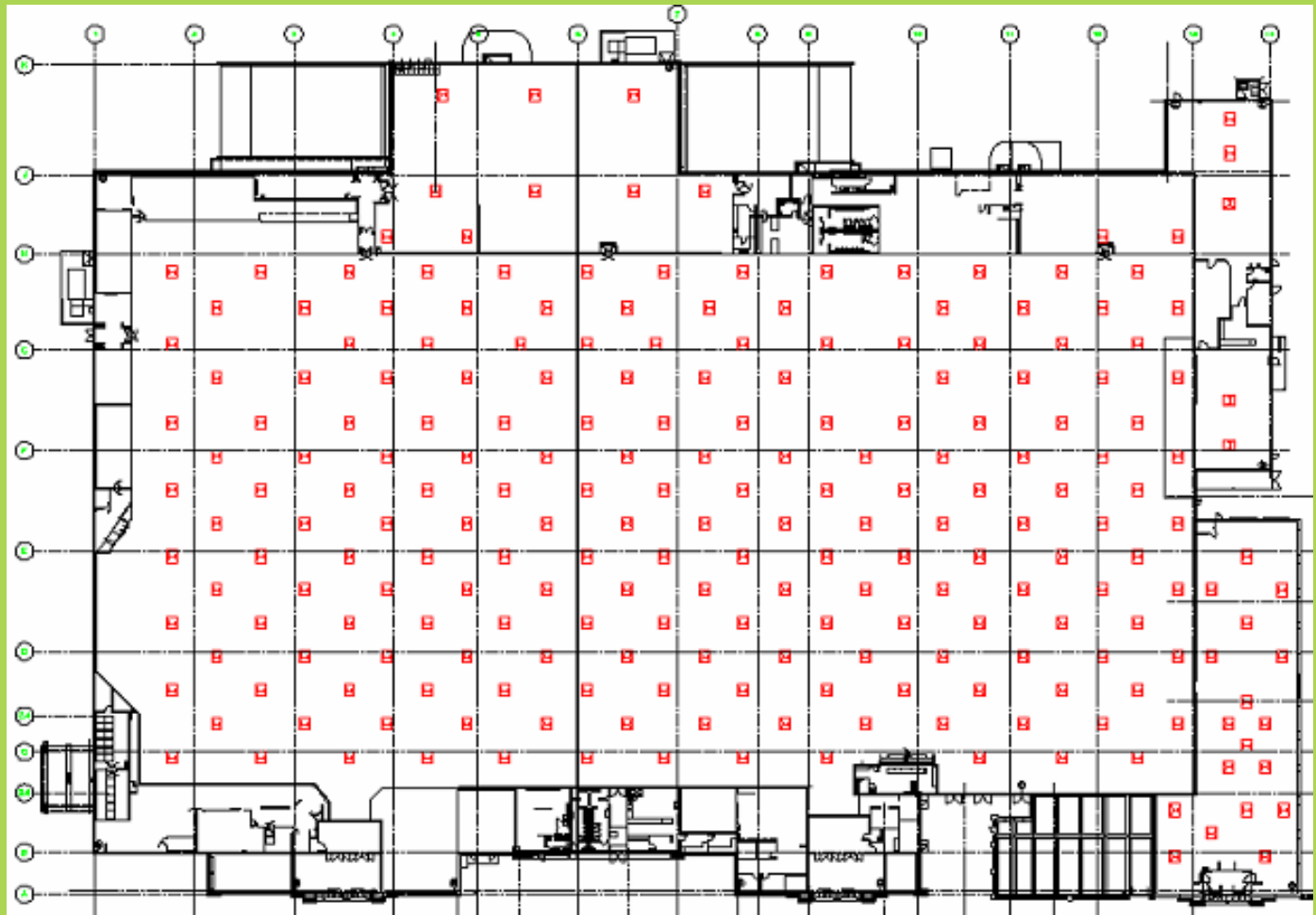
## Skylight Roof Layout

### Why Daylighting?

- Energy savings
- Enhances visibility
- Increases Retail Sales (?)
- Enhances Color Selection

### Design Parameters

- 193 5'x6' Prismatic Units on Sales
- Approximately 40' x 34' grid
- Skylight to Floor Ratio=4%
- Curb Height (well)=16"



Wal-Mart  
Daylight  
Harvesting

# Skylight Roof Layout



# Wal-Mart Daylight Harvesting

# Interior Completely Day Lit





# Wal-Mart Daylight Harvesting

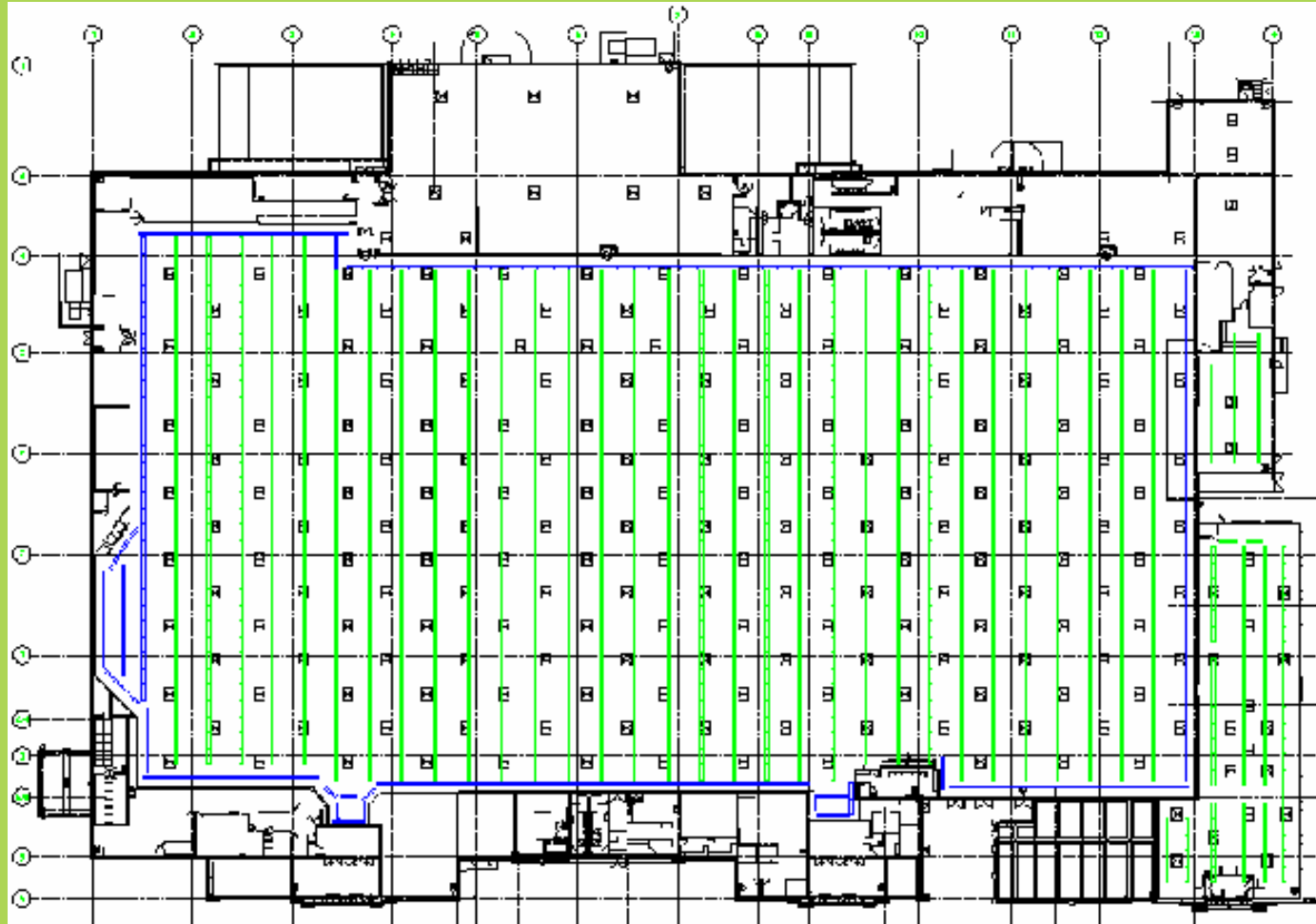
## Present Lighting Design

### Current Sales Floor Lighting Design

- 1,024 lights on Sales Floor & TLE Sales Area in 195 proto at 149 watts (W) each
- 1.18 high efficiency ballast
- Total watts = 152,576
- 1.2 W per square foot
- Lighting controlled by energy management system – automatically dimmed by system when sufficient light is provided via the skylights

#### Perimeter Lighting:

- 213 perimeter lights in 195 proto
- 114 watts each
- Total watts = 24,282



\* Current Design – Lighting wattage is better than ASHRAE 90.1 allowed wattage by 41% and qualifies for the maximum tax advantage under EAct 2005

# Wal-Mart Daylight Harvesting

## Proposed Lighting Design

### Proposed Sales Floor Lighting Design

- 1,024 lights on Sales Floor and TLE Sales Area in 195 proto at 116 watts (W) each
- 0.88 high efficiency dimming ballast
- Total watts = 118,784
- 0.97 W per square foot
- 22% energy savings

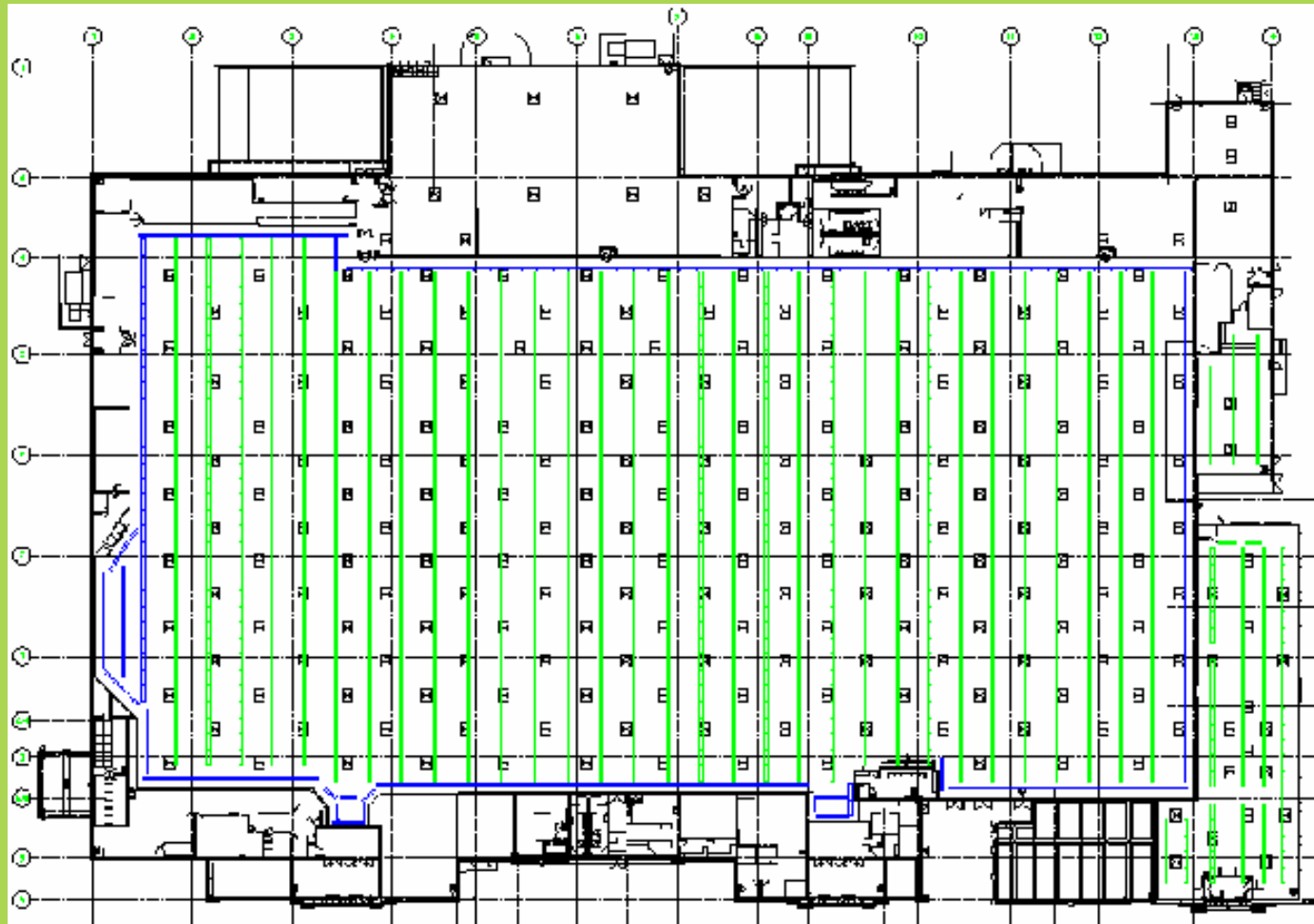
#### ASHRAE 90.1:

Allowed lighting wattage for Retail Sales, Wholesale Showroom – 1.9 watts /sq-ft

#### Energy Policy Act of 2005 (EPAAct 2005):

Building rebate based on reducing energy and power usage by 50% based on reference building per ASHRAE 90.1 based on:

- Interior lighting systems
- Heating, cooling, ventilation and hot water systems
- Building envelope



\* Proposed Design – Lighting wattage is better than ASHRAE 90.1 allowed wattage by 49% and qualifies for the maximum tax advantage under EPAAct 2005

## Future Daylight Optimization?

Model the building to determine if there is an advantage to optimize the daylight system by geographic and climatic region

Investigate better skylight material ( IR additive and selective films) to reduce solar gain but provide the similar visible light transmittance

Solar Indexing of the control parameter set points to account for solar incident angles (Time of year, time of day, etc.)

Optimize control system algorithms and timing to provide fast and smooth dimming of the electric lighting in response to daylight changes

Provide Daylighting in Offices and other non-retail areas of the building

# Wal-Mart Daylight Harvesting

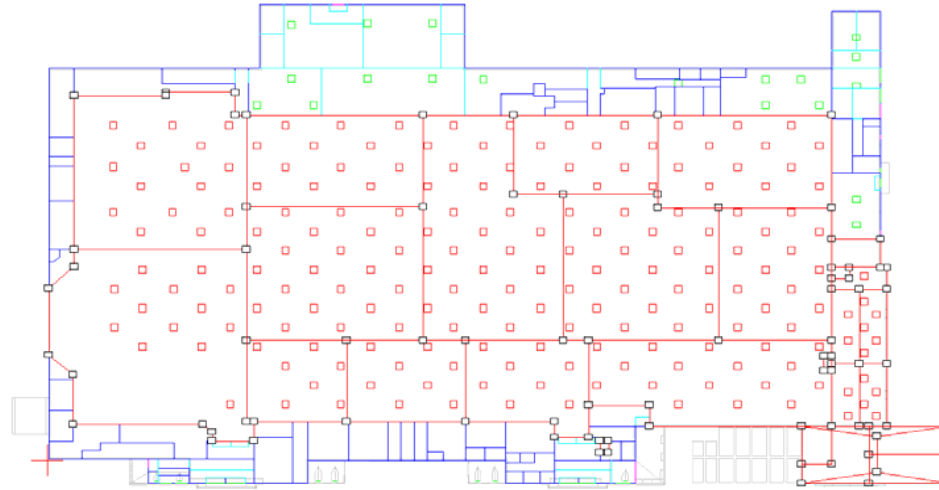
## Skylight Configuration Model

### Overview of Model Skylight Configuration

- Skylights defined in Virtual Environment model with 'current' proto layout
- Thermal/optical properties:
  - U-value = 2.4 W/m<sup>2</sup>K
  - Shading coefficient=0.72
  - Light transmittance=0.70
- Total area equals  $\approx$  4.5% of roof area

Alternative configurations considered:

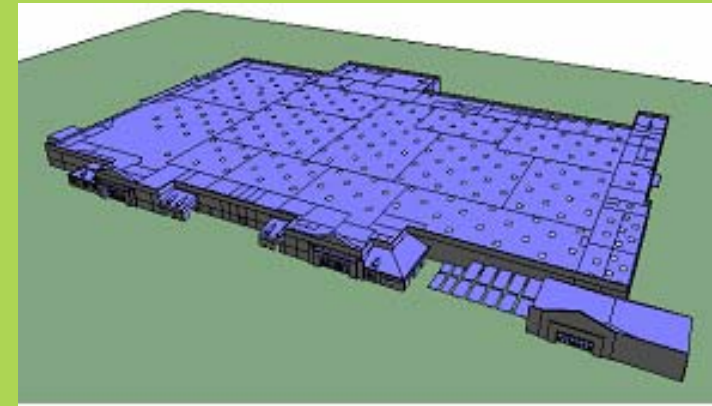
- 0% of original area
- 50% of original area
- 200% of original area



### Summary data

- Heat gain = 15.31 W/m<sup>2</sup>
- Radiant fraction = 0.45
- Power consumption = 15.63 W/m<sup>2</sup>

### Plan and perspective views of 'baseline' model (standard 195 proto)



- Information from Study by Integrated Environmental Solutions in 2005



## Wal-Mart Daylight Harvesting

# Skylight Tests and Evaluation



Current version of Solatube skylight used in Aurora, CO for use in offices and break rooms

**Questions?**



# Questions & Discussion

# Announcements



Summer Energy Savings ideas and guidance – on the web

- [www.energystar.gov/buildings](http://www.energystar.gov/buildings)
- [www.energystar.gov/industry](http://www.energystar.gov/industry)

Take the ENERGY STAR Challenge

- [www.energystar.gov/challenge](http://www.energystar.gov/challenge)

# Upcoming Web Conferences



July 26\* – Using Energy Information Services Strategically

August 16 – State-of-the-art Sub Metering

September 20 – Remote Monitoring and Control System

October 19 – Energy and Climate Risk Management

Download past web conference presentations at:

[www.energystar.gov/networking](http://www.energystar.gov/networking)

Questions or comments? Contact: [tunnessen.walt@epa.gov](mailto:tunnessen.walt@epa.gov)



Thank You!