Energy Efficient Lighting Strategies
Sharing a vision on High Performance Lighting in the Pursuit of Zero Energy

Brad Oberg, Chief Technology Officer
Big Picture

- We are about creating the confidence for builders to make energy efficient lighting choices
- Codes and incentive programs create an interest
- Lighting historically has been an underutilized design feature and many times is relegated to an allowance and a showroom sales person.
- It wouldn’t take much to include good lighting design in more homes
- An integrated design-build-sell process is needed
Energy Efficient Lighting Strategies
LED lighting has become a major medium for art, because of its vibrant color and low energy demands.

Battery powered displays are used in point of sale through safety and more!

Energy efficient lighting may soon become the norm in homes as well.
Lighting, Appliances, and Miscellaneous Electric Loads

- Lighting: hardwired and plug-in
- Appliances: big 5 major appliances
- MELs: plugged in equipment and other loads
Cold Climate

- Large variances of rain, temperature & geography
- Lots of basements and crawl spaces
- Lots of moisture stresses
- Forced air systems – metal ductwork
- Chicago, Denver, Minneapolis, Pittsburgh, Indianapolis
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Mixed Humid

- Similar variances of rain & temperature
- Large variances of elevation
- Basements and crawl spaces
- Lots of moisture stresses
- Heat Pumps - Forced air systems – flex duct
- Charlotte, Atlanta, Louisville, Dallas

Energy Efficient Lighting Strategies
• Intense solar load
• Moisture a challenge
• House types and styles vary greatly
• AC almost always installed
• Heat pumps - forced air systems, flex duct
• Houston, Orlando, West Palm, Atlanta, New Orleans
• Intense solar radiation
• Avg. rainfall of <20”/yr, but can receive large quick rain amounts
• Improper irrigation techniques can lead to moisture problems
• Slab on grade construction
• Mixture of exterior finish products – stucco predominate
• Tucson, Sacramento
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Interior Hardwired

Exterior Hardwired

Plug-in Lights
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Lighting: Interior Hardwired Distribution

- Living Room and Dining Room
- Kitchen
- Entry, Hall, Stairs, and Mud Room
- Loft and Hall
- Bedroom #3
- Master Bedroom
- Bedroom #2
- Master Bath
- Basement
- Bath #3
- Bath #2

Percent of Annual Lighting Energy

- 20%
- 18%
- 16%
- 14%
- 12%
- 10%
- 8%
- 6%
- 4%
- 2%
- 0%
# Whole House Model

## Lighting Power Densities

<table>
<thead>
<tr>
<th>Areas</th>
<th>Base Lighting</th>
<th>Efficient Lighting</th>
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<tbody>
<tr>
<td>0-Basement</td>
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<td>1-Dining</td>
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<td>1-Laundry</td>
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<td>1-Library</td>
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<td>1-Powder</td>
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<td>1-Garage</td>
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<td>2-Bedroom 2</td>
<td>1.6</td>
<td>0.4</td>
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<tr>
<td>2-Bedroom 3</td>
<td>1.8</td>
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<td>2-Bedroom 4</td>
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<td>2-Closet</td>
<td>1.2</td>
<td>0.6</td>
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<td>2-Foyer</td>
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<td>0.5</td>
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<tr>
<td>2-Hall</td>
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<tr>
<td>2-Master Bath</td>
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<td>2-Master Suite</td>
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<td>2-Stair</td>
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<td>0</td>
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<tr>
<td>Attic</td>
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</table>

(Note: 1 indicates first floor; 2 indicates second floor.)
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Whole House Model

Schedules - Lighting
Whole House Model

Schedules - Occupancy

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Whole House Model

Annual Site Energy Use

- Minn-Base
- Minn-Eff
- Wash-Base
- Wash-Eff
- Phoe-Base
- Phoe-Eff

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Why is lighting so personal?

Vision is a partnership between the brain and the eyes.

We have been conditioned since pre-history to manage that partnership for survival.
Lighting quality is measured subjectively by our reaction based on deeply trained responses.

- S/A (Satisfaction/Activity) at 70fc
- Esteem at 50fc
- Roles in Society at 35fc
- Safety at 20fc
- Physiological at 4fc
DESIGN CONSIDERATIONS: COLOR

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Color shift and short life issues plagued the CFL market in the last 2000’s.

**ENERGY STAR “Durability” Testing**

Work ongoing at Lighting Research Center

Source: US EPA
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Fixture Inventory on Website

- Recessed Downlight
- Wall Washer
- Strip Light in Cove
- Under-Cabinet Light
- Ceiling Surface Light

Fluorescent: New fixture and design choices
Light Sources and Options

- Change Bulb
- Change Fixture
- Change Design
Model E27-WLX3
3 Watt Luxeon (3 x 1 Watt)
LED Medium Base Spot
Light - 120 VAC

light output comparable to 25~30 watt incandescent

50,000 Hours Life Time
Warm White (3400K) –
49 lumens

Available with 10 or 30
degree beam pattern
Housing Material:
Aluminum and ABS Plastic

UL listed
OSTAR®-Lighting LED Light Source

The OSTAR®-Lighting LED light source was developed with an emphasis on the areas of general lighting such as:

- Room Lighting
- Architectural/Effect Lighting
- Industrial Lighting
- Radiators and Spot Lighting
- Flashlights

However, it is also suitable for special applications such as:

- Microscope Lighting
- High-quality Flash Lamps
- Traffic Signs
- Operation Lighting in Medical Technology

Figure 2: OSTAR®-Lighting with lens (LEW E3B)
The advantage of the chip coating is that the converter can be applied to the chip surface in a homogeneous layer with uniform concentration. This causes the converted light to be nearly constant across the entire chip surface. Typically, the color temperature of the OSTAR®-Lighting lies in the range of 4500 to 7000 K (daylight white), with a color reproduction index (CRI) of 80.

Figure 3: Color groups, color temperature and spectrum of the OSTAR®-Lighting
Color Temperature

- Not consistent in market
- Leads to consumer dissatisfaction
- Murky yellow at 2700K
- Greenish cast at 4100K

Color Rendition Is a Barrier

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Color temperature

Range of Daylight

Warm | Neutral | Cool | Cold

1800K | 2200K | 2800K | 3000K | 3500K | 4100K | 5000K | 6500K | 7500K | 9000K | 10000K

Setting Sun

Range of Flame

Range of Incandescent and Halogen

Range of Fluorescent

North Sky

Energy Efficient Lighting Strategies
# Recommended Fluorescent Lamps for Common Use

<table>
<thead>
<tr>
<th>Desired Lamp Color</th>
<th>Lamp Color Designation</th>
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<tbody>
<tr>
<td>Warm 2700K</td>
<td>“827”</td>
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<tr>
<td>Warm 3000K</td>
<td>“830” or “930”</td>
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<tr>
<td>Neutral 3500K</td>
<td>“835”</td>
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<tr>
<td>Cool 4100K</td>
<td>“841”</td>
</tr>
<tr>
<td>Cold 5000K</td>
<td>“850” or “950”</td>
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</table>

Example: F32T8/830 is a 3000K, 32 watt tubular fluorescent lamp 8/8” in diameter
Note the diminished power at the purple end of the spectrum.

UV is absorbed by the longer path through the atmosphere.

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Incandescent spectrum is continuous with an emphasis at the red end.

Fluorescent spectrum is dominated by the phosphors used as the coating on the tube. Some fluorescent lamps have three or four phosphors, creating different results when viewing an object.
High Pressure Sodium Light Source

Color shift during warm up

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Intro to LED light source

Early LED’s are one color chip. CFL is a tri-phosphour source with multiple bands.

Newer LED’s can excite different base chip to form white light. Best to date is a white chip at 130 lumens per watt.
LED Color
Metal Halide is a broad spectrum based on the base metal materials.
You can see the spectral distribution too!

Light in here

Look Here
Energy Efficient Lighting Strategies

Incandescent spectrum is continuous with an emphasis at the red end.

Fluorescent spectrum is dominated by the phosphors used as the coating on the tube. Some fluorescent lamps have three or four phosphors, creating different results when viewing an object.
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Color Temperature
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Color Temperature

1. DAY LIGHT
   6500K  CRI  85

2. BRIGHT WHITE
   5000K  CRI  85

3. COOL WHITE
   4100K  CRI  78

4. 3500K  SP. HIGH CRI

5. SOFT WHITE
   3000K  CRI  85
Color Rendering Index is an indication of the ability of a lighting source to accurately communicate the actual color of a subject under a full spectrum light source.
This image of Color Rendition Index is inaccurate in that the image is uniformly de-saturated.

Alternative lighting sources more correctly are of non-uniform saturation, emphasizing only a few colors.
Change in primary color saturation

CR: 100

CR: 60

CR: 60

CR: 60
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- **Tungsten**: 7-24 L/W
- **Halogen**: 12 - 36 L/W
- **Mercury Vapor**: 20 - 63 L/W
- **Metal Halide**: 60 - 125 L/W
- **Compact Fluorescent**: 44 – 80 L/W
- **T-12, Circle T-12 Fluorescent**: 44 – 80 L/W
- **T-5 Fluorescent**: 44 – 80 L/W
- **T-5 HO**: 98 L/W
- **T-8**: 100+ L/W
- **T-5**: 105 L/W
- **Low and High Pressure Sodium**: 60 - 180 L/W
- **LED BEST**: Efficiency

<table>
<thead>
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<th>Lumens per watt</th>
<th>Watts</th>
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Service Life

- Quartz
- A-19 Tungsten
- CFL’s
- T-8
- T-5 Circle
- T-5HO
- T-12
- T-5
- LED Bright White
- LED Colors

Hours of Life vs. Watts

- Watts: 0, 50, 100
- Hours of Life: 0, 5000, 10000, 15000, 20000
Lighting Examples

Let’s look at some real examples
1. The lead time to get fixtures is unreasonable
2. My show room is not knowledgeable
3. The cost is too high
4. Heat has been and always will be a major contributor to short life
5. Design of fixtures don’t match my décor
6. Adapted light fixtures don’t use new light sources optimally
7. Light output is not the same level
8. Light output is not the same character
9. Light output is not the same color
10. My electrician doesn’t do/know about/care to install
Build in Test Homes

Hedgewood - GA

Tindall - NJ

Kacin (Malky) - PA

TNAH 05 - FL

Aspen - CO

Summerset Green - PA

Southern Living Home - GA
Harvard Leading a market of voluntary standards

Stapleton Community:

All voluntary energy standards

Progression from Code plus to many builders building at 50% better than code
Builder is building high efficiency and experimenting with specifications that approach Zero Energy.
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Harvard Communities

Under Cabinet

Surfaces
Harvard Communities

Living Room Toward Deck

Living Room

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Living Room Accents

Energy Efficient Lighting Strategies
Harvard Communities

Master Bedroom

Learning about Valences

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Energy Efficient Lighting Strategies

Harvard Communities

Master Closet

Toilet Room
Harvard Communities

Dual Purpose

Office Loft

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Harvard Communities

Hallways

Stairs
Harvard Communities

CFL - Acceptable

LED - Unacceptable

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Small custom builder leading through energy efficiency and style
All lighting energy efficient sources

CFL and Linear as well as some LED
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studio26 homes
Learning how to communicate the character and differences of lighting options to a builder

Making the need to make lighting choices more evident
Visualize the shape of the light

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Create context settings
Kitchen and under cabinet lights generate a lot of interest.
Kitchen and under cabinet lights generate a lot of interest
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Fixture Position
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Lighting Inventory
Is performance related to what you pay?

T-2 vs T-5?

LED?
LED High end fixture

- Good light color
- Less light
- High cost
Lighting Design Guide

Master Bedroom - Indirect Cove Lights

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