Efficient Lighting Design - PCC
Summer Sustainability Institute
Efficient Lighting Design

• Importance of efficient lighting
• Lighting science
• Color quality
• Lighting design
• Light sources
  – CFLs
  – Fluorescent fixtures
  – LEDs
• Controls
The Energy Independence and Security Act of 2007

Two significant provisions:

**Effective January 1, 2012**
Eliminates manufacture of most general-service incandescents.
All general-service lamps (including CFL, LED, incandescent, or halogen) must

- Have minimum color rendering index (CRI) of
  - 80 if not a “modified spectrum” lamps; or
  - 75 if a “modified spectrum” lamp; and
- Prove minimum efficiency (basically 30% more efficient than today)
## EISA 2007

<table>
<thead>
<tr>
<th>Phase Out (yr.)</th>
<th>Lumen Ranges</th>
<th>Watts</th>
<th>Efficacy (lumens/watt)</th>
<th>Rated Lumen Ranges</th>
<th>Maximum Rate Wattage</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>1600</td>
<td>100w</td>
<td>16</td>
<td>1490-2600</td>
<td>72w</td>
<td>21-36</td>
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<tr>
<td>2013</td>
<td>1100</td>
<td>75w</td>
<td>14.67</td>
<td>1050-1489</td>
<td>53w</td>
<td>20-28</td>
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<tr>
<td>2014</td>
<td>800</td>
<td>60w</td>
<td>13.33</td>
<td>750-1049</td>
<td>43w</td>
<td>17-24</td>
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<tr>
<td>2014</td>
<td>450</td>
<td>40w</td>
<td>11.25</td>
<td>310-749</td>
<td>29w</td>
<td>11-26</td>
</tr>
</tbody>
</table>
What about Reflectors?

- Most popular reflectors eliminated include 50W and 75W R20 and the 85W BR30.
- Consumer demand expected to shift to halogen lamps
- CFLS more energy efficient but dimmability options are limited
State Codes

• OR
  – N1107.2 High-efficiency lighting systems
  – 50% of fixtures to be outfitted 40 lumens/watt

• WA
  – 505.3 Outdoor Lighting
  – Outdoor high efficacy luminaires
  – PROPOSED 2010: 50% indoor luminaires

• CA
  – Title 24
  – Efficient lights and controls
Building Programs

Provide differentiation and preparation for code changes

- Northwest ENERGY STAR Homes
- NAHB
- Built Green
- Earth Advantage
- LEED for Homes
Why else?

Love for Mother Earth!
Understanding Color Quality

R-O-Y-G-B-V
Color Quality

- Primary colors of light: **Red, Green, Blue**
- RGB Principle
- TVs, CFLs, etc.
Color Quality

Light is energy. Spikes in intensity effect color quality
Color Temperature (CCT)

Cool

- Daylight
- Sunlight
- Metal Halide (MH)
- Halogen

Common Fluorescent Range

- Incandescent
- High Pressure Sodium (HPS)
- Candle

Warm

- Daylight
- Cool White
- White
- Warm White

6500
5000
4100
3500
3000
2700
2200
1500
Color Rendering Index (CRI)

- CRI – HOW A BULB REPRODUCES COLOR ACCURATELY

CRI SCALE RANGES FROM 0 – 100

** ALL ENERGY STAR CFL’S INTENDED FOR INDOOR USE ARE 80 CRI OR HIGHER.

- Best: 100
- Excellent: 80 **
- Good: 70
- Poor: 50
- Bad: 25
- Worst: 0
• Evenly balanced

• All wavelengths of visible light present in nearly equal quantities

• Continuous Spectrum
• Output curve shows little radiation in the lower end of the spectrum

• Appears warm in color

• Renders Reds better than blue despite CRI of 100
• Improved triphosphor coating

• More pronounced energy bands in the primary colors

• Improving both CRI and Efficiency
• Intense concentration of spectral energy in the yellow portion of the spectrum

• Unable to render colors accurately
Lighting Design basics

• How much light

• How to light

• Additional tips
How much light

- The amount of light required for good vision depends on three factors:
  - Age
    - 50% more light at 50 than 25
    - Sensitivity to glare increases with age
  - Speed and accuracy required
    - Size of Detail
    - Time of Exposure
  - The reflectance of the task
    - Contrast
    - Luminance
Size of object being illuminated

Size of object being illuminated

Size of object being illuminated

Size of object being illuminated

Size of object being illuminated

Size of object being illuminated

Size of object being illuminated
Time of Exposure

TA
EBG
MRL
FLH
Contrast

color + light
Luminance
How to light

• Ambient Lighting
  – General illumination to move about
  – Creates ambience

• Accent Lighting
  – Draws eye to important
  – Creates drama/impact

• Task Lighting
  – Light to work by
Additional techniques.... That I roll up

- **Architectural Lighting**
  - C&I focus
  - Accent lighting application to light architectural elements

- **Decorative Lighting**
  - Fixture chosen on style or décor
  - Provides dual lighting purpose as ambient, accent or task

- **Wall Lighting**
  - Cans along perimeter of wall or sconce
  - Increases scale of the room
  - Adds comfort
  - Generally is grouped in as ambient or accent
Good Lighting Design

• Light in layers
  – Single fixtures = Glare bombs and dark corners
• Select lights based on what and how you want to light
• Apply correct technology to application
• Lighting quality is more important than quantity
• Consider separate controls
Additional Design Tips

• Under Cabs
  – Install at edge of cabinet (far from wall)
  – Angle back to wall not straight down
  – Attention to countertop surface and glare/hot spots
Additional Design Tips

• Dining Room Pendants and Chandeliers
  • Typical dining rooms accept a 4-6 light, 26-30” diameter chandelier OR
    – width or diameter or table less 12”
    – 1/3 or greater table size
  • Tall dining rooms and entries often need 2- and 3-tiered designs
  • 30” from base of light fixture to table surface at 8ft ceiling height (add 3” to suspension height for every foot of ceiling height
  • More than 2 feet from ceiling
Additional Design Tips

• Pendant Bowls – Dining room
  • Dining room pendant bowls are typically 20-48” and must be mounted above eye level so you don’t see into them while standing

• Pendants and Mini-pendants – Kitchen Island
  – Mini-pendants should be about 1 pendant per 3 feet of countertop length
  – Hung high enough to see under them standing and to keep food splatter off over island appliances
Additional Design Tips

• Track Lighting
  – Highly flexible!
  – Can create shadows on work surfaces in kitchens
  – Pendant options help in kitchen
  – Aim heads to avoid direct line of sight
Recessed Design Tips

Wall Washing

- 2 to 3 feet from wall
- Clean ceiling plane
Recessed Design Tips

Recessed Cans

- Can be used to provide ambient light levels
- Avoid 4 foot on center grids
Recessed Design Tips

Wall Grazing

- 6 to 12 inches from wall with 1:1 spacing ratio
- Produces scallops
- Great for enhancing texture
Recessed Design Tips

Recessed Cans

– Poor facial modeling: use multiple cans
Recessed Design Tips
Recessed Design Tips

Trim options and glare
Inefficient Lighting products

- Incandescent
- Halogen
- Halogen IR
- Quartz Halogen
- Xenon

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Residential Efficient Lighting

General Ambient Light Sources:

- **CFLs**- general ambient light source designed to replace incandescent lamps in residential applications

- **Fluorescent fixtures**- decorative or linear options for general ambient light source

Task/Accent Light Sources:

- **LEDs**- New technology for residential task lighting. Although some LED products are very efficient, market inconsistencies exist
CFL Applications

- Enclosed fixture bulbs
- Dimmable bulbs
- Reflector bulbs in cans (HEAT)
- Globe covered bulbs for bath
- A-line covered bulbs
- Candelabra bulbs
- Torpedo bulbs
ENERGY STAR CFL Benefits

• Great Color
  • Color rendering index > 80
  • Color Temperature 2700K, 3000, 4100, 5000, 6500

• Stringent Performance Requirements
  • Start Time average of <1 second
  • Run-up Time Maximums: Not to Exceed
    • 3 minutes (covered, amalgam lamps)
    • 1 minute (bare spiral lamps with dosing)
  • Lumen Depreciation at 40% rated life shall not be more than 20%
ENERGY STAR CFL Benefits

- Long Life: spec 6,000 hrs., most last 8,000
- High Efficacy Requirements
  - Min. efficacy 50-65 l/w (bare spirals)
  - 40-60 l/w (covered lamps)
  - 35-55 l/w (candelabra base)
- 2 year warranty
- Wide variety of Lamp Options
  - Specialty covered CFLs available
  - Some dimmable CFLs
- Retrofits of incandescents is a breeze
- Multiple light output options
Decorative CFL Fixtures

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CFL Fixtures

ENERGY STAR decorative fixtures use a 10,000 hour pin- or GU24-based fluorescent bulb which ensures long-term savings.
ENERGY STAR CFL Fixture Benefits

• Great Color
  – CRI of 80 or better
• Long-term efficiency
  – Pin and GU bulbs last 10,000 hours
  – Save over life of fixture
• Thermal design- no hot spots!
• Minimum efficacy 50-70 lumens per watt
• 2 year fixture warranty
ENERGY STAR CFL Fixture

Benefits

• Features of Ballast
  – Removable ballasts
  – Minimum requirements for power quality, color quality & noise rating
• Documentation of independent lab testing
• Excellent bulb fit every time
• Decorative options to fit any decor
• Eliminate burden of proper CFL selection and application
CFLs- Room for Error

- 2 of 4 lamps are CFLs
- Proper size CFL
- Globe or A-line covered CFLs
CFLs- Room for Error

- Proper size CFL
- Install vanity up
- Globe, A-line or Flame covered CFLs
CFLs- Room for Error

Cans are (unfortunately) taking over modern lighting

- Proper size CFL - MOL
- wing nuts inside of can provide necessary adjustability
- High Heat
LEDs and SSL

Solid-state lighting (SSL) technology uses semi-conducting materials to convert electricity into light. SSL is an umbrella term encompassing both light-emitting diodes (LEDs) and organic light emitting diodes (OLEDs).

LEDs are non-carbon based materials that provide light when an electric current passes through it.

OLEDs are carbon based materials that provide a diffuse light source over large surfaces.
LED Systems

• LEDs are sold as a system with the diode, heat sink, optics and driver.
LED Language

LED Chip

LED Lamp

LED Module (Array)

LED Driver

LED Light Engine

LED System (Luminaire)
LED Lighting Facts Label

Light Output/Lumens
Measures light output. The higher the number, the more light is emitted. Reported as "Total Integrated Flux (Lumens)" on LM-79 test report.

Watts
Measures energy required to light the product. The lower the wattage, the less energy used per hour and is reported as "Input Power (Watt)" on LM-79 test report.

Lumens per Watt/Efficiency
Measures efficiency. The higher the number, the more efficient the product. Reported as "Efficacy" on LM-79 test report.

IESNA LM-79-2008
Industry standardized test protocol for measuring performance quality of LED luminaries and integral lamps. It allows the user to compare luminaire regardless of the light source.

Registration Number
Unique number given to each manufacturer's design product once it has been registered, verified, and approved. Only products with valid registration numbers may display the Lighting Facts label.

Model Number
Unique manufacturer's model number for the product.

Type
Specific type of solid state lighting fixture.

Brand
The brand the product is available under.

Color Rendering Index (CRI)
Measures color accuracy. Color rendering is the ability of the lamp's light spectrum to represent the color appearance of objects.

Correlated Color Temperature (CCT)
Measures light color. "Cool" colors have higher Kelvin temperature (6000-6500K); "Warm" colors have lower color temperature (2700-3500K).

Light Output (Lumens) 270
Watts 6.8
Lumens per Watt (Efficacy) 39

Color Accuracy
Color Rendering Index (CRI) 76

Light Color
Correlated Color Temperature (CCT)
3500 (Bright White)
Warm White 2700K
3000K
4500K
5000K
6500K
Bright White
Daylight

All results are according to IESNA LM-79-2008: Approved Method for the Electrical and Photometric Testing of Solid-State Lighting. The U.S. Department of Energy (DOE) verifies product test data and results. Products qualified under the DOE ENERGY STAR program have the ENERGY STAR mark on this label.


Registration Number: D1QF-46X39H
Model Number: DL-t5W
Type: Portable desk lamps

FTC Mid-2011 requirement for all lights

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ENERGY STAR LEDs

DOE developed ENERGY STAR standards for LED light products

Eligible September 20, 2008 in following categories:

• Under-cabinet kitchen lights
• Shelf mounted display and task lights
• Portable desk lamps
• Recessed down lights
• Outdoor wall mounted porch lights
• Outdoor step lights
• Outdoor pathway lights
ENERGY STAR LEDS

201 approved ENERGY STAR LEDS as of July 2010

- Efficacy testing
- LM80: 9 month (chip) life test
  - Do they really last forever?

TM 21 TESTING IN DEVELOPMENT
LEDs last ‘forever’

Cree White Xlamp Long Term Lumen Maintenance
(Ambient Temperature = 25C, Junction Temperature = 65C)
Benefits of LEDs

Great for task and accent lighting

LEDs

• ‘Chemical-free lighting’
• Cold resistant
• Vibration tolerant
• Long Life
• Extremely efficient- system measurement
• Technological improvements of LED light quality and efficacy every day- Careful of unproven claims!
Technologies to watch

OLEDs

- Large sheets
- Efficient alternative for ambient lighting
- Claim to emit natural light through the organic materials.
Technologies to watch

**ESL**, electron-stimulated luminescence
- Accelerated electrons light up a phosphor coating on the inside glass
- Instant start
- Dimmable
- Light quality similar to incandescent and halogen
- No trace mercury as in CFLs
- Less manufacturing energy than LEDs
- Product launch planned for mid-2009 with initial focus on reflectors
Controls

- Dimmers
- Timers
- Occupancy Sensors
  - Passive Infrared (moving heat)
  - Ultrasonic (doppler)
  - Microphonic (sound)
  - Combination for obstructions
- Photocells
Dimmers

Rheostat (variable resistor)  vs.  Solid state switching device

OLD  vs.  NEW
Solid State Switching Dimmers

120 cycles per second
Dimmers
Alternative Dimming
# Dimmers

<table>
<thead>
<tr>
<th>Dimming lights</th>
<th>Saves electricity</th>
<th>Effects bulb life</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INCANDESCENT &amp; HALOGEN BULBS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15%</td>
<td>15%</td>
<td>3 times longer</td>
</tr>
<tr>
<td>25%</td>
<td>20%</td>
<td>4 times longer</td>
</tr>
<tr>
<td>50%</td>
<td>40%</td>
<td>20 times longer</td>
</tr>
<tr>
<td>75%</td>
<td>60%</td>
<td>20 times longer +</td>
</tr>
<tr>
<td><strong>CFLs</strong></td>
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<td></td>
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<tr>
<td>15%</td>
<td>15%</td>
<td>Potential to shorten life</td>
</tr>
<tr>
<td>25%</td>
<td>25%</td>
<td>Potential to shorten life</td>
</tr>
<tr>
<td>50%</td>
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<td>Potential to shorten life</td>
</tr>
<tr>
<td>75%</td>
<td>75%</td>
<td>Potential to shorten life</td>
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</tbody>
</table>

*Savings provided by Lutron Electronics Co., Inc.*
Thank You!

Questions?

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