

The Art of Lighting *(and why it matters)*



THE AURORA
CHASERS

Brad Jackson, PE



Goals

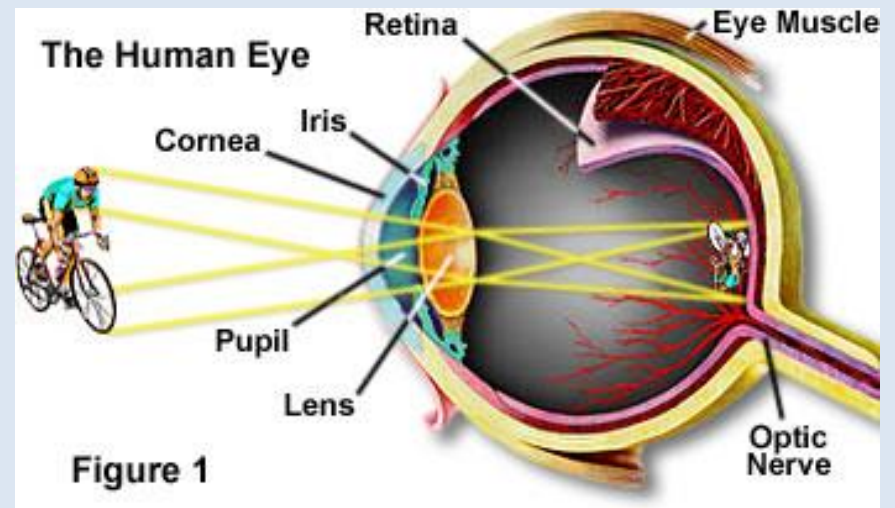
- Who cares about lighting design?
- What IS lighting design? (And how do we do it?)
- What is GOOD lighting design?

Light is the magical ingredient that makes or breaks a space; it's one of the most important elements in all my interiors.

~Benjamin Noriega-Ortiz

Who Cares?

- **Everyone!**
- Light (both natural and artificial) is how we see and perceive the world.
- Light, reflected off the world around us, powers one of the most impressive organs in the natural world.



Who Cares?

- **People who interact with the built environment**
- Offices, homes, schools, churches...
- The people who build them...
- The people who maintain them...
- The people who pay the power bills...

Architecture is the learned game, correct and magnificent, of forms assembled in the light.

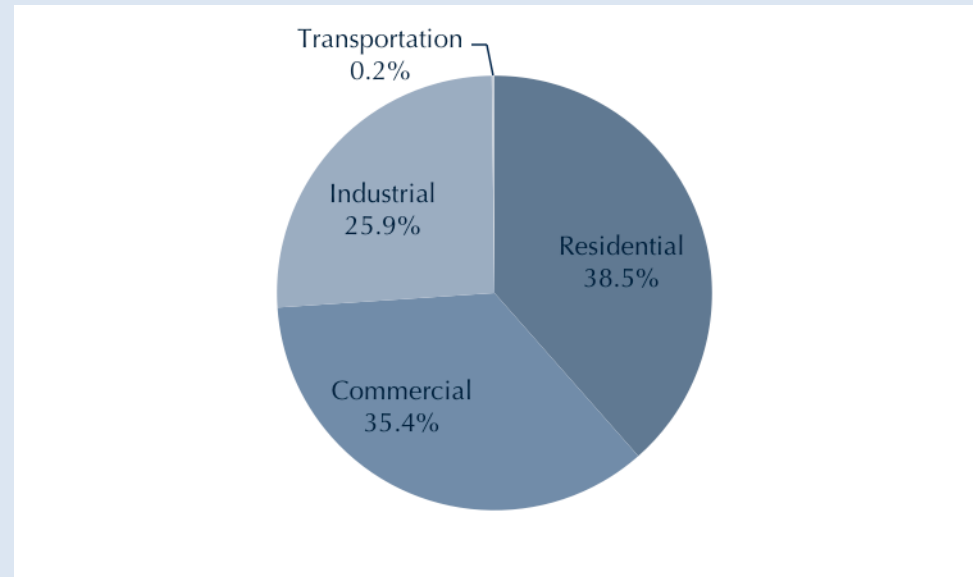
~ Le Corbusier



Who Cares?

- **Total electricity use by sector (2010)**
- **Residential:**
38.5%
- **Commercial:**
35.4%

Retail Sales of Electricity to Ultimate Customers,
Total by End-Use Sector (2010)



Source: U.S Energy Information Administration (EIA), *Electric Power Monthly*, Table 5.1, September 2012.

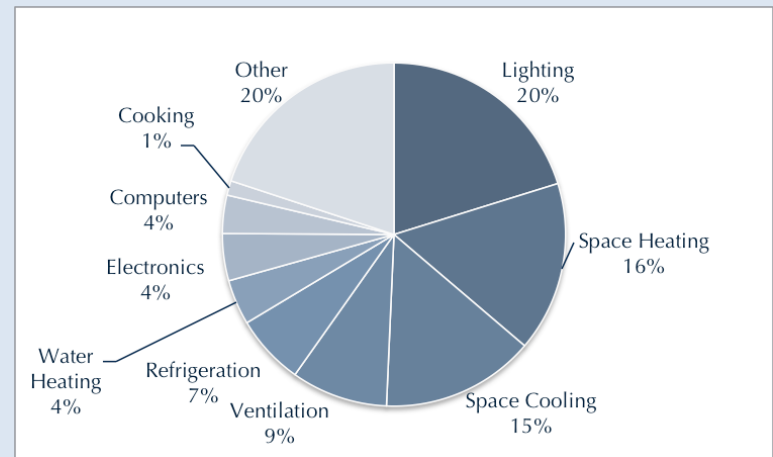
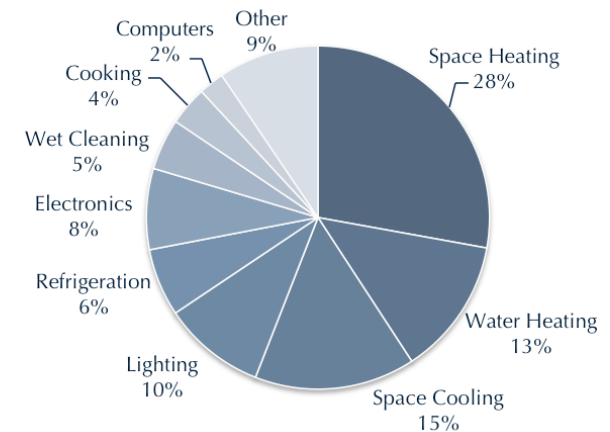
Who Cares?

- Residential lighting use (2010)

10%

- Commercial lighting use (2010)

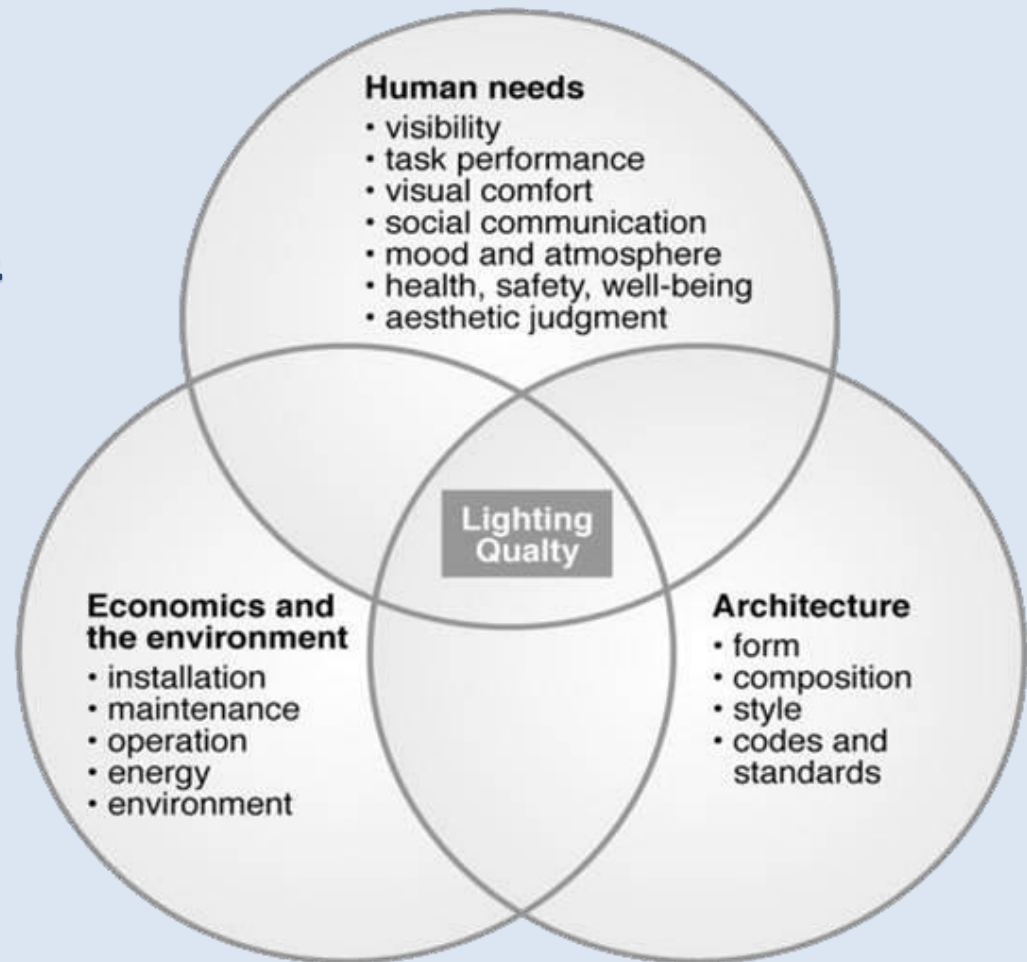
20%



Source: DOE, 2011 *Buildings Energy Data Book*, Sections 2.1.5 & 3.1.4, March 2012.

What is GOOD lighting design?

- By designing better lighting we can:
 - Reduce energy use
 - Increase productivity & well-being
 - Highlight & accent the built environment we live, work, & play in



Lighting Design

- **Metrics and Terminology**
 - Illuminance (what do feet have to do with candles?)
 - Color temperature
 - Color rendering
- **Good Design Principles**
 - Light sources
 - Power consumption & efficiency
 - Luminaire distributions
 - Contrast
 - Directionality & shadows
 - Controls

Illuminance

- For interior lighting, we're concerned with:
- Illuminance

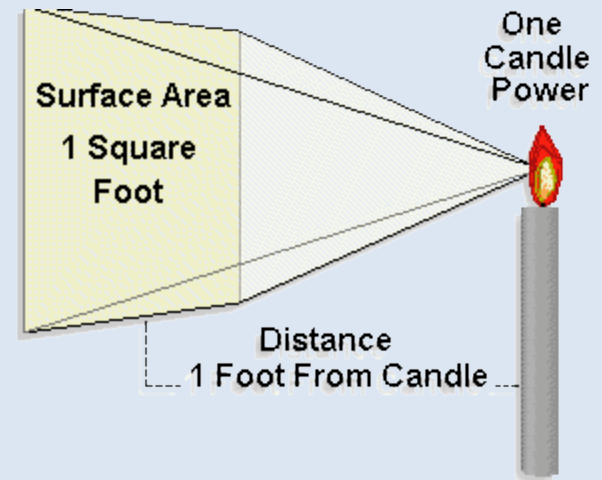
(i.e. the amount of light falling on a predefined area)

- Measured in footcandles (or lux in SI units)
- Don't confuse with brightness (luminance)
- Illuminance is easier to measure & calculate (independent of surface)

- Lumens

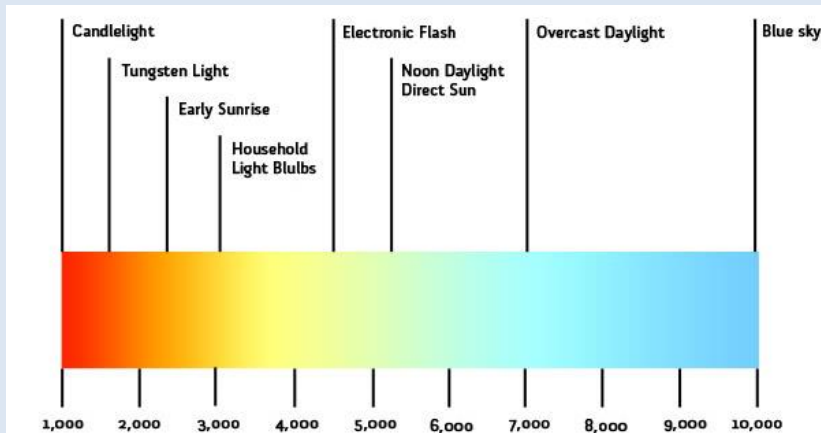
(i.e. the amount of light given off by a source)

- Absolute value
- Bare lamps with no shades are efficient (but NOT good lighting design)



Color Temperature

- Measured in degrees kelvin (think heat)
- Effect of how the light is produced (spectrum)
- Which is better? (totally subjective)
 - However: cooler temp LED sources are more efficient



Color Rendering

- All vision is perception of reflected wavelengths of light
- (Somewhat) Subjective scale from 0-100
(incandescent filament lamps score a 100)
- For fluorescent & LED sources: higher CRI is slightly less efficient (but always better than an incandescent lamp)



DOE Lighting Facts

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.
Reported as "Input Power (Watts)" on LM-79 report.

Lumens per Watt/Efficacy
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 procedure that measures performance qualities of LED luminaires and integral lamps. It allows for a true comparison of luminaires regardless of the light source.

**Registration Number
Model Number
Type**

LED lighting facts®
A Program of the U.S. DOE

Brand X

Light Output (Lumens)	840
Watts	9
Lumens per Watt (Efficacy)	93
Color Accuracy Color Rendering Index (CRI)	87
Light Color Correlated Color Temperature (CCT)	2900 (Warm White)

Warm White Bright White Daylight
2700K 3000K 4500K 6500K

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.

Visit www.lightingfacts.com for the Label Reference Guide.

Registration Number: ABC435TH4792003
Model Number: 18756CHT56428954R3HT1234H3
Type: 18756CHT56428954RGHT1234H3

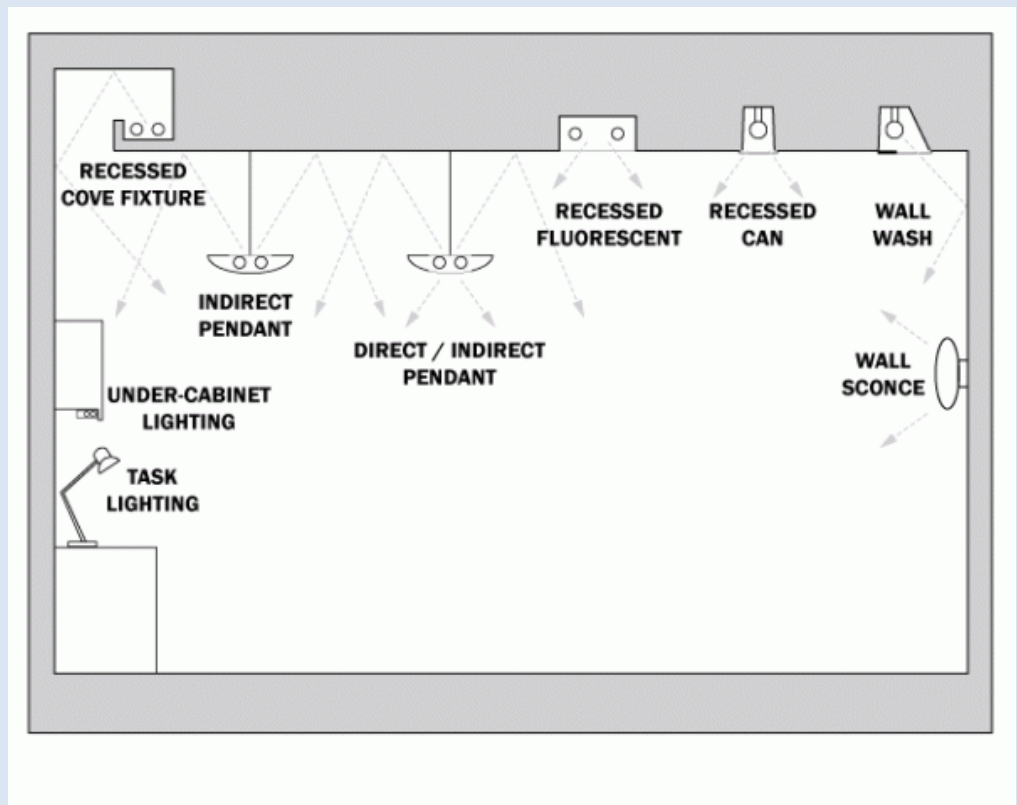
Brand

Color Rendering Index (CRI)
Measures color accuracy.
Color rendition is the effect of the lamp's light spectrum on the color appearance of objects.

Correlated Color Temperature (CCT)
Measures light color.
"Cool" colors have higher Kelvin temperatures (3600–5500 K); "warm" colors have lower color temperatures (2700–3500 K). Color temperatures higher than 6500 are outside of the defined region for white light, but may be appropriate for outdoor applications.

Luminaire Distributions

- Bare lamps are efficient (but they don't look great)
- Consider where you want your light to go (and for what effect & purpose)
- 1st: Highlight tasks & features
- 2nd: Assure adequate safety lighting
- 3rd: Really consider if you need more light



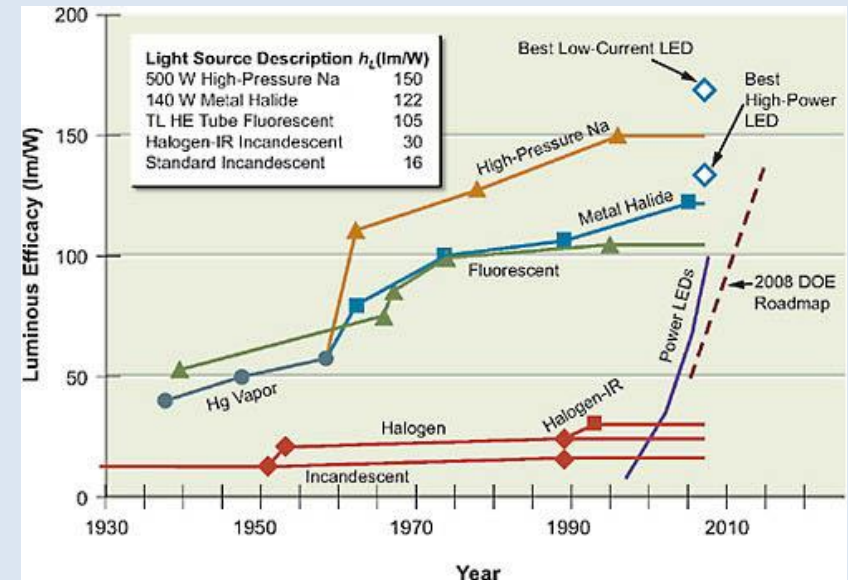
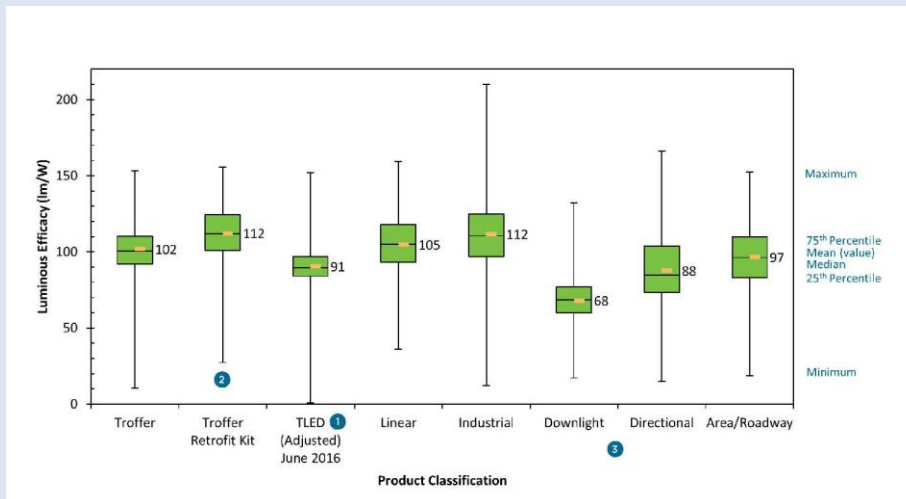
Shadow & Contrast

- Think like an artist
- Pay attention to:
 - Direction (glare)
 - Intensity
 - Features and relief
 - Contrast



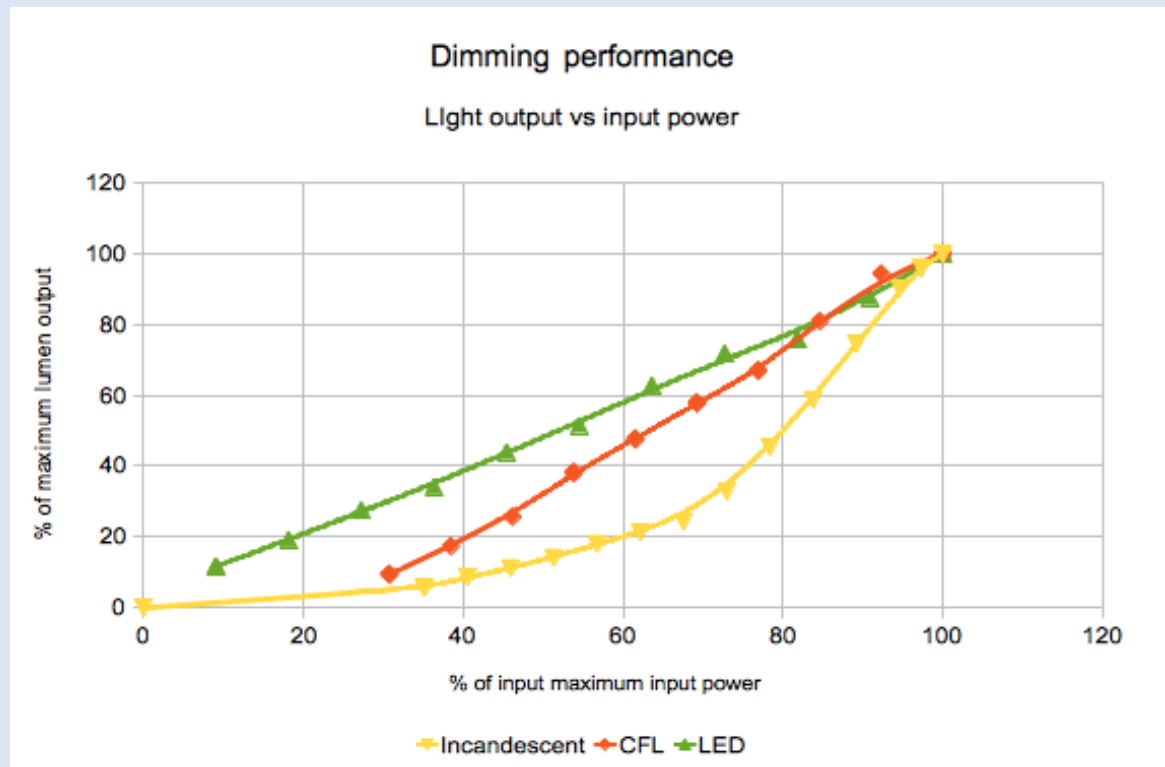
Light Sources & Efficacy

- Legacy sources (HID, incandescent) are being de-emphasized by most lamp manufacturers
- Mean efficacy reached 102 lumens/watt in the recent (2016) DOE Snapshot of LED troffers



Controls & Energy Savings

- 2011 NEC Added requirement for neutrals to all switchboxes (even residential) which allows for advanced (smart) control installation
- LEDs and CFLs have higher (than incandescent) efficacies when dimmed
- Just make sure your lamp (LED or CFL) or driver/ballast is dimmable



Controls & Lamp Life

- LED lifespan is shortened by heat, meaning they last longer when dimmed (20-30%)
- LED source life isn't shortened by frequent switching (unlike incandescent & fluorescent)

Light Source	Typical Life at Full Light (h)	Typical Life When Dimmed (h)
Incandescent	750-1500	1500-6000
Halogen	3000-5000	3000-20000
Non-dimmable CFL	6000-8000	N/A
Dimmable CFL	8000-10000	De-rated
Fluorescent	15000-40000	No change
Non-dimmable LED	20000-50000	N/A
Dimmable LED	20000-50000	Increases

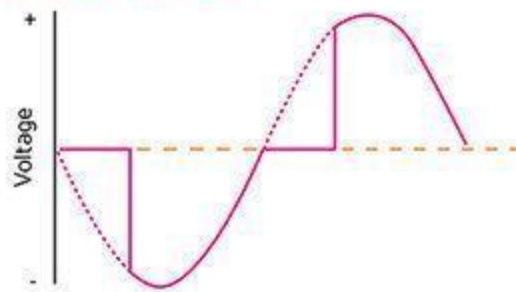
Dimming Technologies

- Line voltage dimmers (phase cut)
- 0-10V dimming
- Digitally addressable controls
 - Many different proprietary “languages”
 - DALI (non-proprietary)
- DMX512 (mostly theatrical & high-end architectural)
- Wireless controls
 - Again, many different proprietary “languages”
 - Zigbee (non-proprietary)

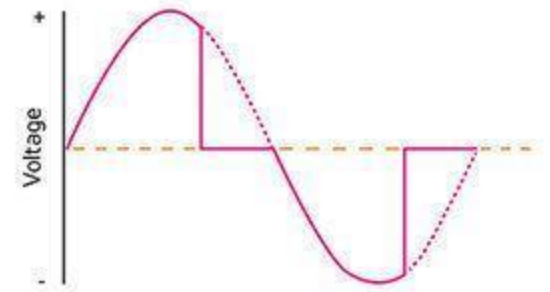
Line Voltage Dimming

- Residential style (slide or rotary) dimmers function by “chopping” the line voltage waveform
- Forward phase (also: Magnetic Low Voltage (MLV), TRIAC dimmer, leading edge)
- Reverse phase (also: Electronic Low Voltage (ELV), trailing edge)
- Important:
These DO NOT work via series resistance

Forward-phase control dimmer (TRIAC)

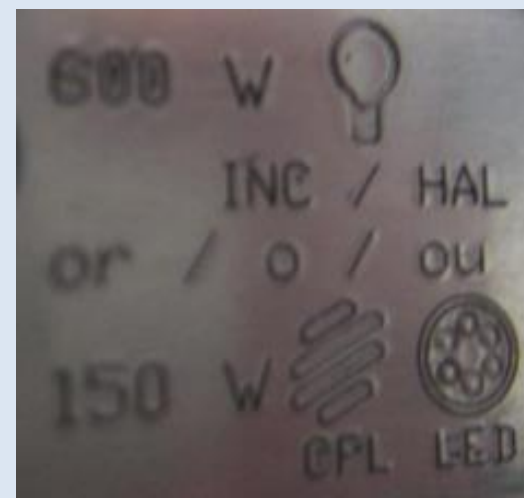


Reverse-phase control dimmer



Line Voltage Dimming, Continued

- **VERY** important to make sure that the dimmer is rated for LED loads
- Pay close attention to the maximum and minimum number of lamps on circuit



Compatible Dimmers for Cree® LED bulbs

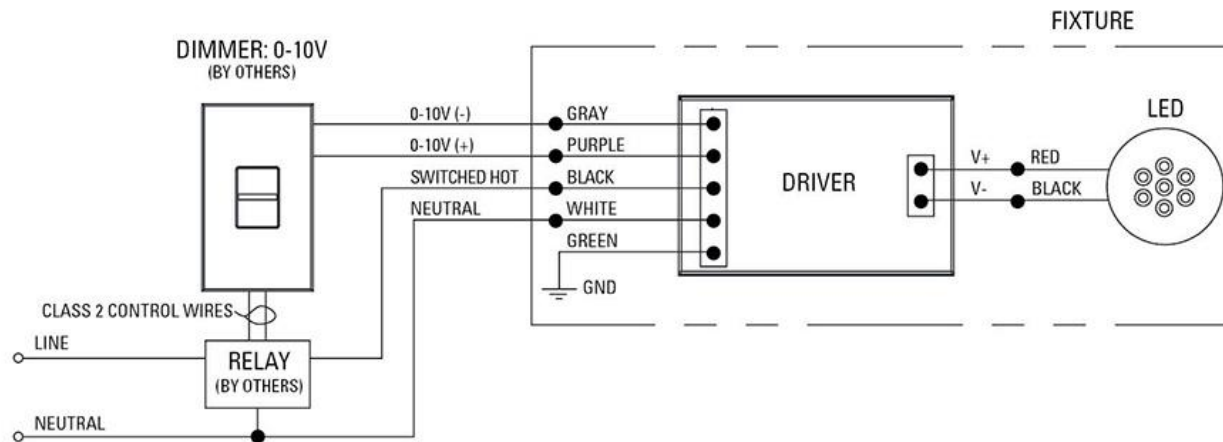
Cree® LED bulbs are designed to be dimmed with standard incandescent type dimmers. They are also compatible with most Magnetic Low Voltage (MLV) and Electronic Low Voltage (ELV) dimmers. This list was generated from lab testing of samples and your results could vary.*



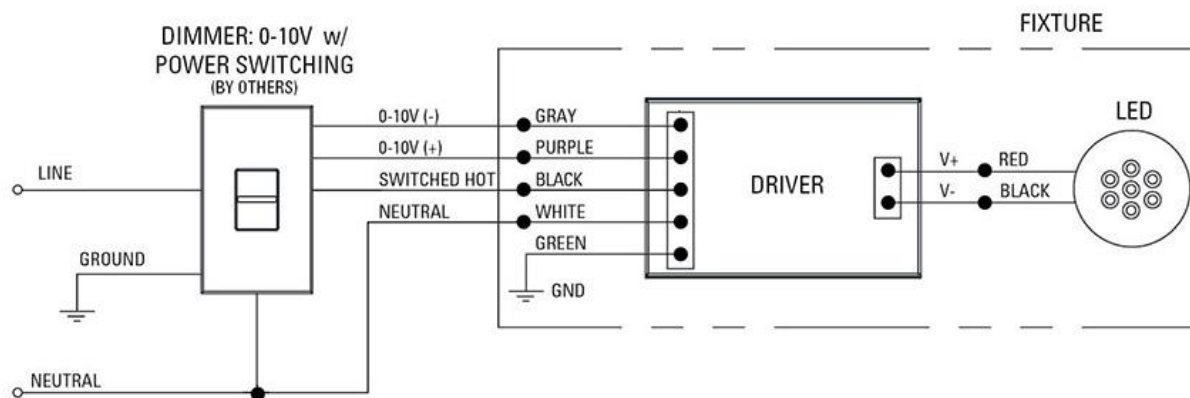
Company Name	Series	Part Number	Load Type	Phase Cut Edge	Dial Control	Rating (W)	bulbs per dimmer	
							min	max
Cooper	Architectural	RA110	Incandescent	Leading	Rotary	1000	2	19
Cooper	Aspire®	9530WS	Incandescent/MLV	Leading	Slide	600	1	8

0-10V Dimming

0-10V DIMMING W/RELAY TO SWITCH POWER



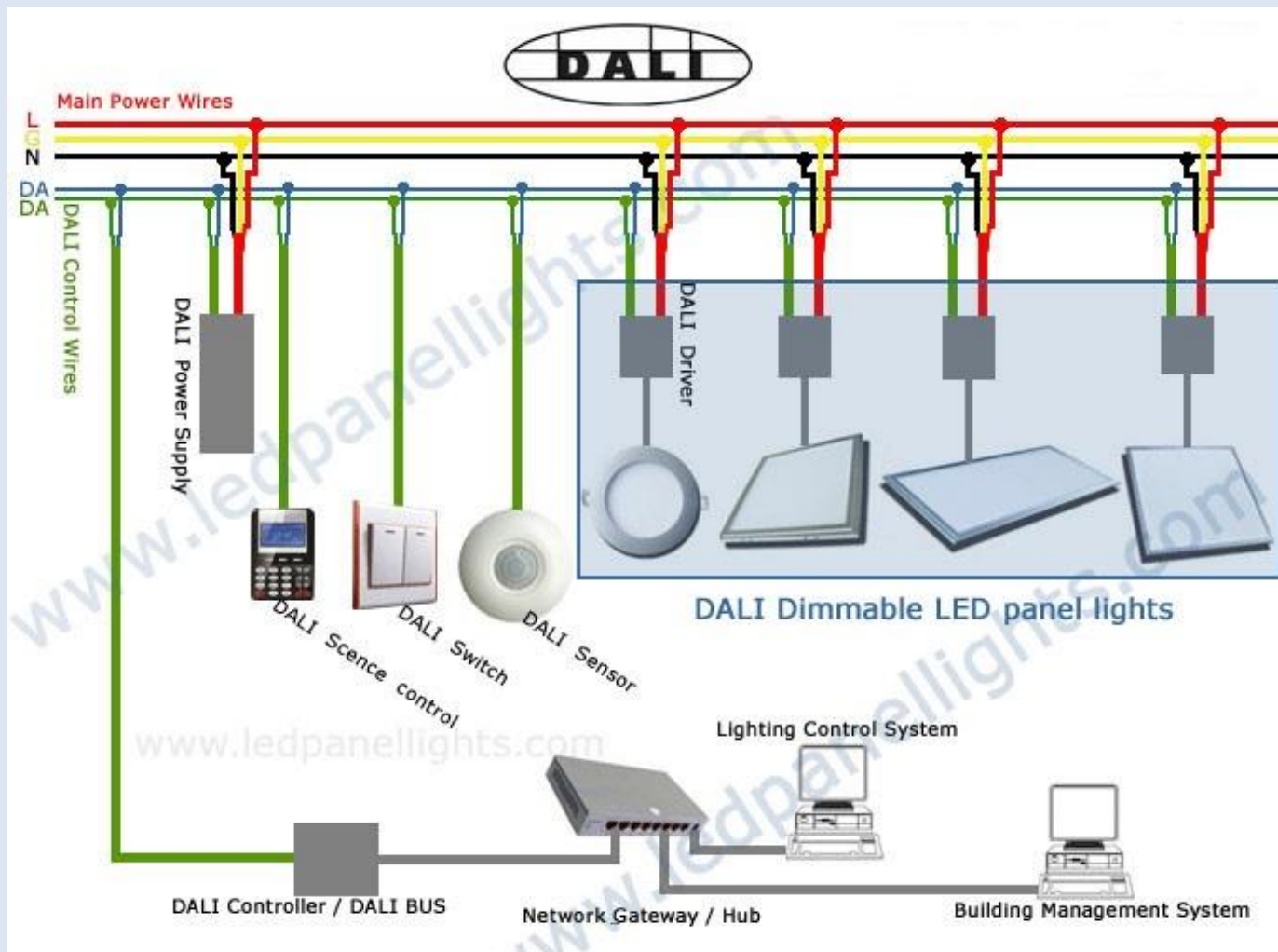
0-10V DIMMING (NO RELAY)



0-10V Dimming

- **Separate 0-10V (usually purple and grey) wires from dimming controller to luminaire or driver**
- **Can be prone to voltage drop over long control wire runs (will cause fixtures to dim inconsistently across large lighted areas)**
- **0 Volts doesn't mean "off" so pay attention to / include provision for line voltage switching / relay**

Digital Control

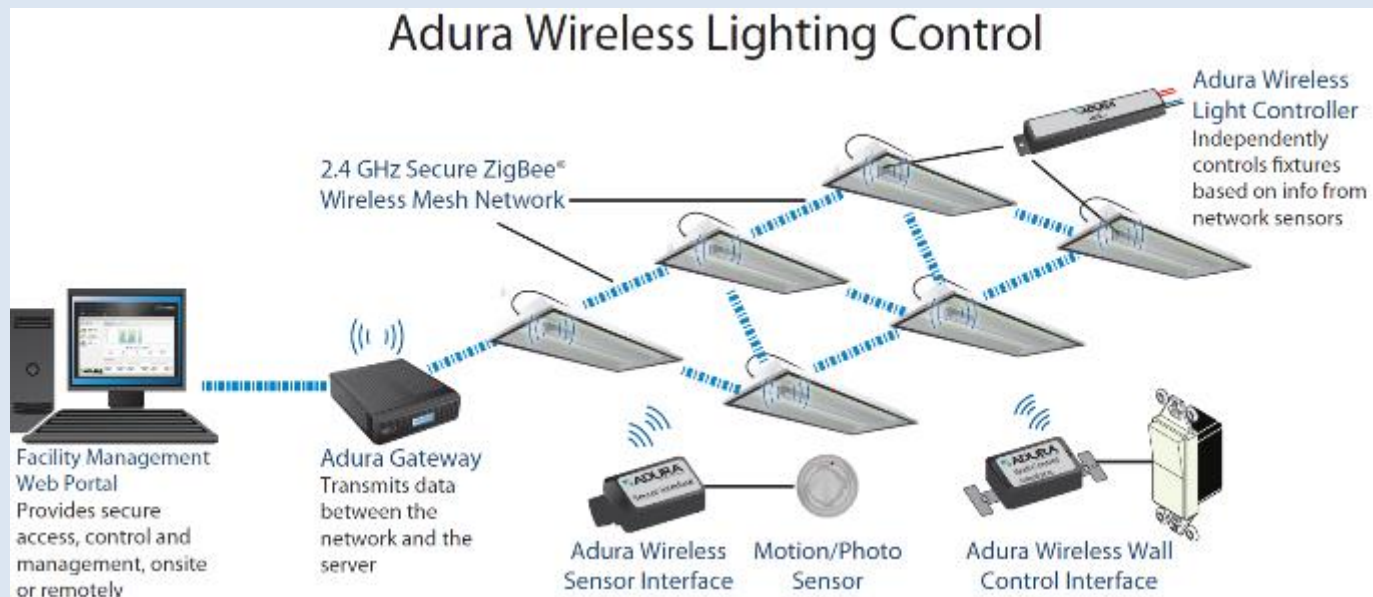


Digital Control

- **Low voltage control wires (usually category cable) runs between fixtures**
- **Allows for individual luminaire level control**
- **Pay close attention to address and signal power limitations**
- **Many control systems now have additional features (occupancy tracking, power metering, BAS integration)**

Wireless Control

- Controls are usually integrated within luminaire
- Luminaires “talk” to each other through a mesh network
- Excellent technology for retrofit applications
- Be careful of signal strength drop through walls



Occupancy and Vacancy Controls

- **Required by energy codes (IECC and ASHRAE 90.1) within enclosed areas**
- **Two sensor detection types:**
 - **Passive infrared (good for motion within line-of-site)**
 - **Ultrasonic (good for motion in hallways and areas with obstructions)**
 - **Dual technology sensors combine both.**
- **Generally classified into two operation types:**
 - **Occupancy - automatic on, automatic off**
 - **Vacancy - requires manual switching on of lights, automatic switching off**

Daylighting Controls

- Automatic dimming of lights based on sun lighting
- Required by energy codes (IECC and ASHRAE 90.1), but redacted from MOA adoption
- Pay close attention to placement of sensors, especially near indirect luminaires and in rooms with automatic (sun tracking) shades

The least energy intensive luminaire...

- Is one that's switched off!
- Though not code required, daylighting controls still represent a huge energy savings for new commercial construction
- It's still a good practice to incorporate sunlight and fenestrations into new construction, along with lighting controls



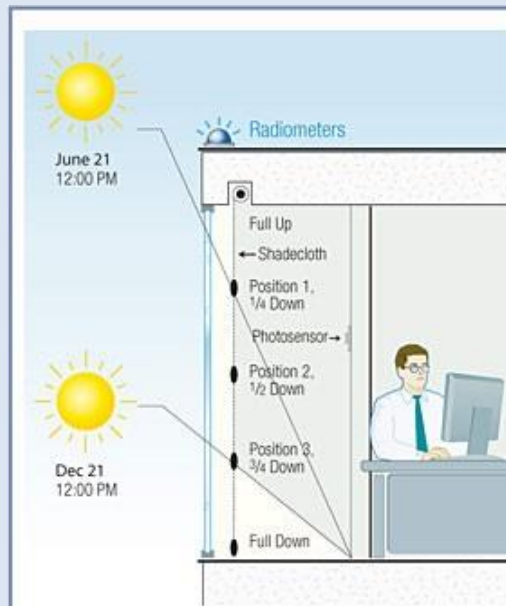
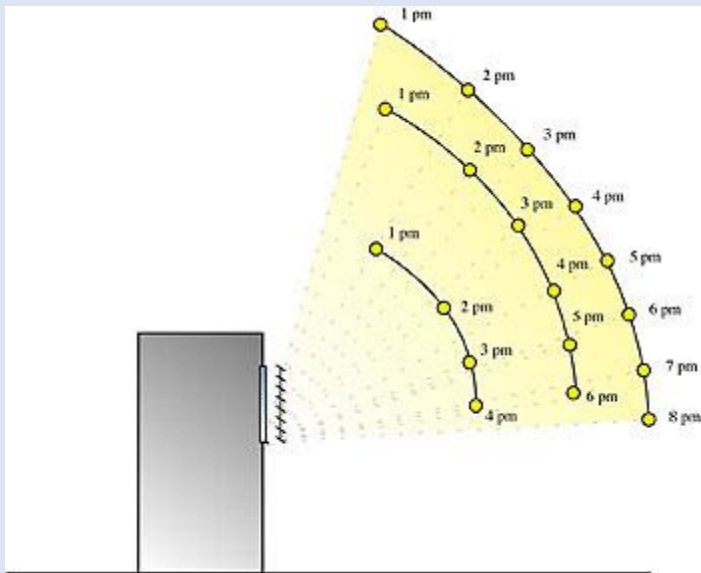
Life in High Latitudes

- However, using sunlight in our state isn't always easy...

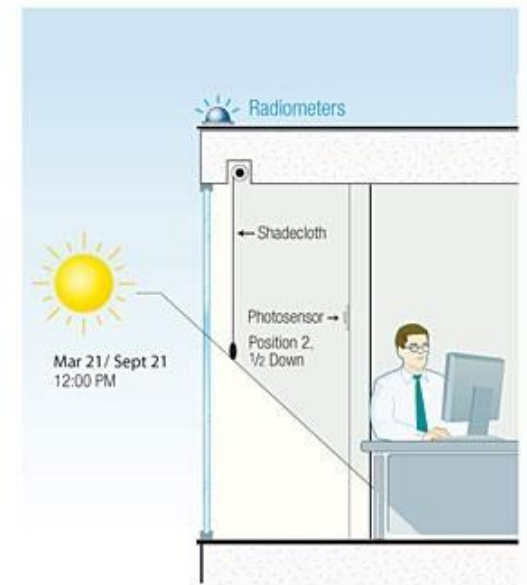


Lighting Controls Aren't Just Switches

- Automatic motorized solar shades
- Passive solar louver shades



Allowable solar penetration summer/winter: June 21/Dec. 21
Peak solar altitudes during the year on the south elevation 40°. North latitude with the SolarTrac® system pre-set to 6 or more positions plus user-defined solar penetration (3 ft./91 cm shown here).



Allowable solar penetration spring/fall: Mar. 21/Sept. 21
Pre-defined shade position is set for the sun angle in the spring or the fall at 5 ft./152 cm.

The Future Looks Bright with New Technologies

- New projects are being designed and built every year throughout the state.
- CTRI's Fireweed Business Center



Innovative New Technologies

- **LEED Silver Certification**
- **LED lighting with daylighting control**
- **Electronically tinting glazing**
- **Insulated light diffusing glass**



Questions?



Thank you!