



Beyond
SMART CITIES

LIGHTING SYSTEMS - CEM REFRESHER
ONLINE TRAINING COURSE

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ENERGY SPECIALIST CURRICULUM





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LIGHTING QUALITY MEASURES
FOR ENERGY PROFESSIONALS

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WHAT SHOULD YOU LEARN





Lighting quality measures



LIGHTING QUALITY MEASURES

- ✓ **Visual comfort probability (VCP)** indicates the percent of people who are comfortable with the glare (brightness) from a fixture
- ✓ **Spacing criteria (SC)** refers to the maximum recommended distance between fixtures to ensure uniformity
- ✓ **Color rendering index (CRI)** indicates the color appearance of an object under a source as compared to a reference source



COMPACT FLUORESCENT EXAMPLE



COMPACT FLUORESCENT LAMPS
For retrofit applications in task lights, wall sconces, downlights, wallwashers, and outdoor fixtures, a wide variety of lamp shapes and types are available. These include globe, capsule, flood, and twin/quadruple units. The most common retrofit applications are in open fixtures with mounting heights less than 12 feet. In some applications, users may prefer to hardwire the ballast in the fixture to prevent replacement with standard incandescent lamps. Lamps with excellent color rendering capabilities (80-90 CRI) are recommended for most indoor applications.

Voltages: 8-265V
Replaces: 25-100W incandescents
Energy Savings: 60-75%
Efficiency: 26-68 lm/W
Lamp Cost: \$3-6
Ballast Cost: \$9-24
Rated Lamp Life: 10,000 hrs
Color Quality: 80-85 CRI
Drawings: not in retrofit applications
Qualifications: These lamps can have starting limitations in heating temperatures, and

operation in enclosed fixtures may shorten lamp and ballast life and reduce light output. Because compact fluorescent lamps are not point sources, other technologies (such as LED lighting) may be more suitable in applications where point sources are required. Some conventional fixture types may not be large enough to accept the larger size of the fluorescent lamp ballast package. Check manufacturer data to determine impact of ballast use on power factor and power quality.

Example: Compact Fluorescent Lamps
Old System: Incandescent lighting
100 natural @ 72 watts @ \$4.50 / hr
Operating hours: 10 hrs/day, 6 days/week (3,600 hrs/yr)

New System: Retrofit fluorescent lamps @ 26 CRI with integrated magnetic ballasts, downlighting reflector ballast @ 60 watts (including fixture), 71% energy savings, virtually unlimited high-lamp-hour allowances; 10 more lamps per ft²

Savings: Demand savings: 5.3 kW, energy @ 24,804 kWh/yr; color @ 24,804 kWh/yr and \$0.08/kWh; \$1,984.32/yr
Net Savings: \$1,140/yr
Cost: Labor: 100 man-hours @ \$4/hr = \$400
Payback: \$2,500/\$1,140/yr = 2.19 yr

CALCULATION FOR COMPACT FLUORESCENT EXAMPLE

- › **kW savings**
- › **100 fixtures (.075 kW/fixture - .022 kW/fixture) = 5.3 kW**
- › **kWh savings**
- › **(5.3 kW)(4680 hrs/yr) = 24,804 kWh**
- › **Demand \$ savings (5.3 kW)(\$4/kW-mo)(12 mo/yr) = \$254.40/yr**
- › **Energy \$ savings (24,804 kWh/yr)(\$0.08/kWh) = \$1,984.32/yr**
- › **Total dollar savings (\$254.40 + \$1,984.32)/yr = \$2239/yr**



T-8 EXAMPLE

Example: T-8 Fluorescent System Retrofit

Old System: Office lighting consisting of 360 fluorescent 2'x4' fixtures; operating hours 14 hrs/day, 5 days/week (3640 hrs/yr); each fixture draws 188 watts with 4 standard cool white 40-watt fluorescent lamps (@ \$2) and 2 standard magnetic ballasts

New System: Each fixture now draws 112 watts with 4 tri-phosphor F40T8 32-watt fluorescent lamps and 1 electronic T-8 instant-start mode ballast*

Results: 40% energy savings; 2% reduction in light level; improved color rendering; 50% fewer ballasts to replace; 25% less lamp life using instant-start mode ballasts

Savings: Demand savings: 27.4 kW; energy savings: 99,600 kWh/yr; dollar savings @ \$4/kW/mo and \$0.08/kWh:

\$9,290/yr; relamping savings: materials <\$612/yr>; labor <\$437/yr>

Net Savings: \$8,231/yr

Cost: Material: 1440 F32T8 fluorescent lamps @ \$3.25; 360 T-8 instant-start mode electronic ballasts @ \$31; labor: 360 installations @ \$20

Total Project Cost: \$23,040

Payback: \$23,040/\$8,231/yr = 2.8 yrs (with 10% a/c factor, payback becomes 2.5 yrs)

*Building codes in some states do not allow all four lamps to be operated by a single ballast. In such cases, two adjacent fixtures can share two ballasts that are wired to leave the two-level switching intact. Assume an additional \$15 wiring cost per fixture. The payback period increases to 3.5 years.

CALCULATION FOR T-8 EXAMPLE

✓ **Demand savings** (360 fixtures)(.188 - .112) kW/fixture = 27.4kW

✓ **Total \$ savings** (27.4 kW)[(\$4/kW-mo)(12 mo/yr) + (3640 hrs/yr x \$0.08/kWh)] = \$9290/yr

FLUORESCENT LAMP LIFE AT VARIOUS BURN CYCLES

Lamp	3	6	10	12	18	24
40-w T12 pre-heat	15,000	17,500	21,250	22,500	25,000	28,125
40-w T12 rapid start	20,000	24,420	27,750	28,860	31,600	37,700
32-w T8 instant start	15,000	17,500	21,250	22,500	25,000	28,125
32-w T8 rapid start	20,000	24,420	27,750	28,860	31,600	37,700

OCCUPANCY SENSOR EXAMPLE

Uncontrolled System: Six conference rooms, each with four 4-lamp fluorescent fixtures (188 watts) operating 10 hrs/day, 5 days/week (2,600 hrs/yr); lamps @ \$2

Controlled System: When conference rooms are unoccupied for longer than five minutes, the fixtures are now automatically turned off; they now operate about 7 hrs/day, 5 days/week (1,820 hrs/yr)

Results: 30% energy savings; no change in fixture appearance or light level

Savings: Energy savings: 3,519 kWh/yr; dollar savings @ \$0.08/kWh: \$282/yr; relamping savings: materials \$7/yr; labor \$19/yr

Net Savings: \$308/yr

Cost: Material: 6 switch-mount occupancy sensors @ \$70; labor: 6 installations @ \$10

Total Project Cost: \$480

Payback: \$480/\$308/yr = 1.6 yrs (with 10% a/c factor, payback becomes 1.4 yrs)

✓ **Energy savings (24 fixture)(.188 kW/fixture)(2600 hrs/yr)(0.30) (\$0.08/kWh) = \$282/yr**



LIGHTING-RELATED HVAC ENERGY

✓ **How much lighting energy becomes a load on the HVAC system?**

➤ **How much heat is generated by lighting?**

➤ **Where does lighting heat go?**

➤ **How does it affect the energy consumption of the HVAC system?**



LIGHTING-RELATED HVAC ENERGY

✓ **Lighting-Related HVAC Energy (kWh) =**
Direct Lighting Energy (kWh) x % of year HVAC System
Operates x % of light heat impacting HVAC load / COP
of HVAC system

✓ **COP = Energy Units Delivered to (Removed from) Space /**
Energy Units Into System



LIGHTING-RELATED HVAC ENERGY EXAMPLE

☑ Lighting-Related HVAC Energy (kWh) Example

= Direct Lighting Energy (kWh) 1000 kWh

x % of year HVAC System Operates 0.5

x % of light heat impacting HVAC load 0.9

COP of HVAC system 3.0

$1000 \times (0.5 \times 0.9 / 3.0) = 1000 \times 0.15 = 150 \text{ kWh}$



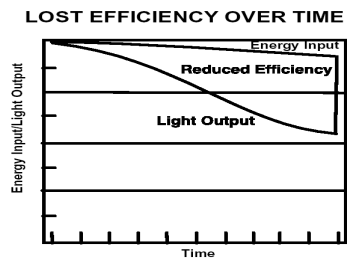
EXAMPLE LIGHTING / HVAC INTERACTION

Location	Cooling Loads	Heating Loads Large Building	Heating Loads Small Building
Tampa, FL	-33%	0%	0%
Phoenix, AZ	-30%	0%	0%
New Orleans, LA	-29%	1%	2%
Los Angeles, CA	-23%	0%	0%
Knoxville, TN	-21%	4%	11%
Philadelphia, PA	-17%	6%	18%
Denver, CO	-16%	7%	22%
San Francisco, CA	-16%	1%	2%
Detroit, MI	-14%	8%	23%
Providence, RI	-13%	7%	22%
Seattle, WA	-7%	4%	13%

☑ Source: Advanced Lighting Guidelines 2003 (based on methodology of Rundquist, et.al. 1993)



NEGLECTED LIGHTING SYSTEMS LOSE EFFICIENCY OVER TIME



LIGHT LOSS FACTORS (LLF)

- ☑ Non-recoverable
 - Luminaire Ambient Temperature
 - Voltage to Luminaire
 - Ballast Factor (BF)
 - Luminaire Surface Depreciation
- ☑ Recoverable
 - Lamp Burnout Factor (LBO)
 - Lamp Lumen Depreciation (LLD)
 - Luminaire Dirt Depreciation (LDD)
 - Room Surface Dirt Depreciation (RSDD)



TOTAL LIGHT LOSS FACTOR (LLF) EXAMPLES

	T12 Spot	T12 Group	T8 Group
LLD	0.82	0.78	0.93
LBO	1.00	1.00	1.00
LDD	0.65	0.80	0.80
Total LLF*	0.53	0.62	0.74

Source: EPA Green Lights



LIGHTING SYSTEM LIFE CYCLE COSTS

- ☑ Initial Costs
- ☑ Energy Costs
- ☑ Maintenance Costs
 - Relamping
 - Reballasting
 - Cleaning
 - Miscellaneous Maintenance
 - Insurance & Property Taxes Depreciation
- ☑ Initial Costs
- ☑ Energy Costs
 - Direct Lighting Costs
 - Lighting-Related
- ☑ HVAC (Indirect) Costs
- Maintenance Costs



DIRECT LIGHTING ENERGY COSTS

☑ Energy Use (kWh) =
Lighting Power (kW)
x Operating Time (hrs)

☑ Energy Cost Savings =
Actual Avoided Costs
(based on rate schedule)



CALCULATING ANNUAL LAMP REPLACEMENTS

Given:

- ☑ 1000 each 3-lamp fixtures
- ☑ Annual fixture operation = 4000 hrs
- ☑ Average rated lamp life = 25,000 hrs

Calculate average annual lamp replacements:

$$\begin{aligned}\text{ALR} &= (1000 \times 3) \times 4,000 / 25,000 \\ &= 3000 \times 0.16 \\ &= 480\end{aligned}$$



BEYOND
SMART CITIES

THANK YOU

THE WORLD'S 1ST GREEN TECHNOLOGY
MARKETPLACE