Lighting Design Strategies for ECBC Compliant Buildings

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ELCOMA Workshop

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Overview

- About ECO-III Project
- Macro Trends in the Power and Building Sector
- ECBC Basics
- Lighting Compliance in ECBC
  - Basic Concepts
  - Lighting Technology
  - Lighting Design
  - ECBC Requirements
- Acknowledgements and Contact Information

About ECO-III Project

- Bilateral Project Between US and India Govt.
- Funded by USAID
- Implemented by International Resources Group (IRG) and ECO-III Partners
- Priority sectors include:
  - Capacity Building of SDAs
    - Energy Conservation Action Plan
    - Pilot Projects
    - Training and Awareness
  - Energy Conservation Building Code
  - Energy Efficiency in Existing Buildings
    - Building Energy Audits and Benchmarking
    - ESCO projects
    - Energy Efficiency in Data Centers
    - Measurement and Verification
    - Case Studies
  - Architectural Curriculum Development
  - Regional Energy Efficiency Centers
  - Small and Medium Enterprises

ECBC Implementation

- Technical Content Development and Capacity Building
  - ECBC (version 2), ECBC User Guide, Tip Sheets, and Design Guides
  - More than 20,000 hard copies of technical resources
  - ECBC professional training module
  - All technical documents posted on ECO-III and BEE web site
- Awareness and Training Workshops on ECBC
  - Organized/Participated in 14 ECBC Training and Awareness workshops
  - Launched a major capacity building effort in building energy simulation
  - Linking ECBC to Architectural Curriculum
- Next Steps
  - ECBC Implementation Framework
  - ECBC Compliance Check Tools
  - Certified Building Energy Professional

ECBC Tip Sheets and ECBC User Guide

ENERGY CONSERVATION BUILDING CODE TIP SHEET

HVAC SYSTEM

Credits:
E Source Technology Atlas
LBNL Tips for Daylighting Guide
Window Systems for High-Performance Buildings
Alliance to Save Energy

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Heating, Ventilation and Air Conditioning (HVAC) refers to the equipment, distribution network, terminals and controls that provide the heating, ventilating, or air-conditioning processes to a building. HVAC accounts for a significant portion of a commercial building's energy use and represents an opportunity for considerable energy savings. This Tip Sheet acts as a primer on energy efficient HVAC systems and proven technologies and design concepts which can be used to comply with the ECBC HVAC provisions.

ENERGY CONSERVATION BUILDING CODE TIP SHEET

BUILDING ENVELOPE

A well-designed building envelope not only helps in complying with Energy Conservation Building Code (ECBC) but can also result in first cost savings by taking advantage of daylighting and correct HVAC system sizing. This document acts as a primer on better envelope design practices and steps needed to comply with ECBC...

Energy Conservation Building Code

User Guide

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ENERGY CONSERVATION BUILDING CODE TIP SHEET

BUILDING LIGHTING DESIGN

Lighting is a major energy consumer in commercial buildings and heat from electrical lighting also contributes significantly to the amount of energy needed for cooling. ECBC prescribes the amount of power that can be used for lighting in buildings, types of lighting controls and encourages use of daylighting. This document (primarily adapted from E Source Lighting Technology Series) provides guidance towards the design of ECBC compliant lighting systems in commercial buildings.

ENERGY CONSERVATION BUILDING CODE TIP SHEET

Version 1.0 — July 2008

ENERGY SIMULATION

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Energy simulation is a computer-based analytical process that helps building owners and designers to evaluate the energy performance of a building and make it more energy efficient by making necessary modifications in the design before the building is constructed. Use of energy simulation software is necessary to show compliance with Indian Energy Conservation Building Code (ECBC) via "Whole Building Performance Method." This Tip Sheet helps in understanding the basic concepts and processes involved in carrying out building energy simulation.

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ECBC Scope

- Sets the minimum energy performance standards for design and construction
- Mandatory scope covers Commercial buildings
  - Connected load in excess of 500kW or Contract demand in excess of 600 kVA
  - Recommended for all commercial buildings with conditioned area 1000 m2 or more
- Applies to New as well as Existing Buildings
- Building components included
  - Building Envelope (Walls, Roofs, Windows)
  - Lighting (Indoor and Outdoor)
  - Heating Ventilation and Air Conditioning (HVAC) System
  - Service Water Heating and Pumping
  - Electrical Power and Motors

Compliance Options

Building System	Compliance Options

Envelope

HVAC

Lighting

Electric Eqpt & Systems

Service Hot Water and Pumping

Mandatory Provisions
(required for most compliance options)

Prescriptive Option

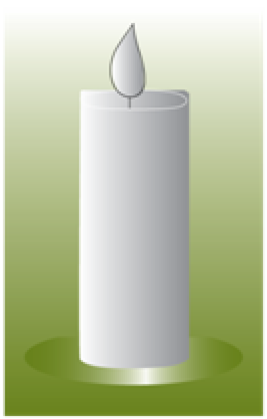
Trade Off Option

Whole Building Performance

Energy Code Compliance

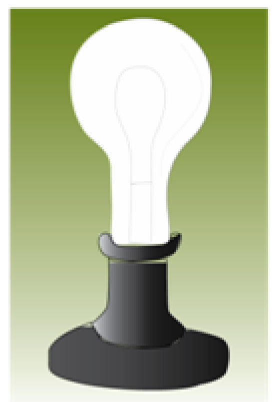
Lighting Design Requirements in ECBC

Candle



12 lm/80 W
0.15 lm/W
7.5-hour life

Carbon-filament incandescent

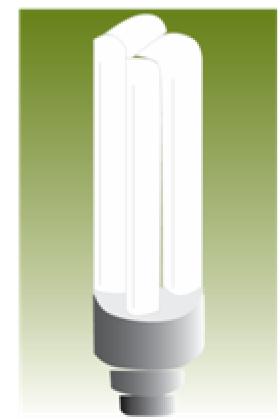


180 lm/60 W
3.0 lm/W
50- to 100-hour life

Tungsten-filament incandescent

730 lm/60 W
12 lm/W
1,000-hour life

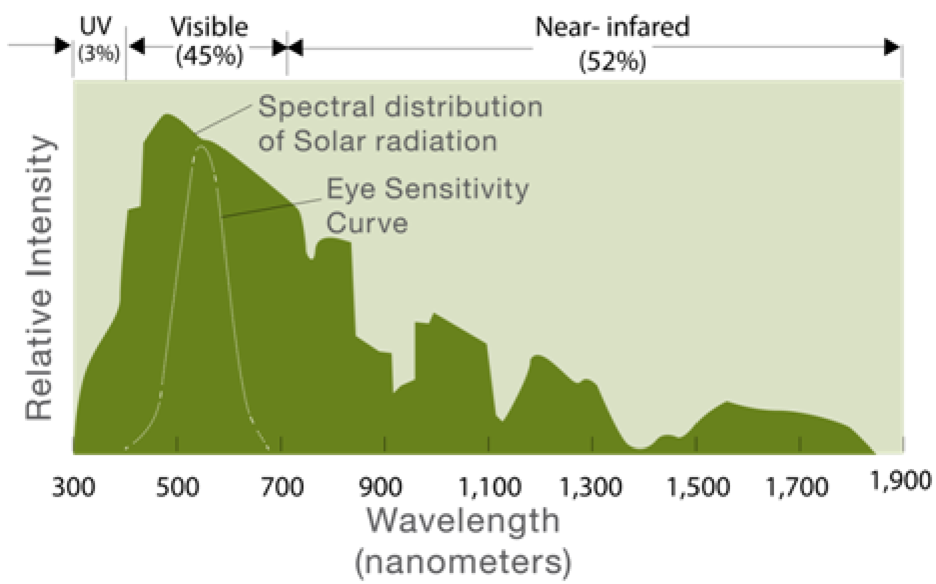
Compact fluorescent



730 lm/13 W
56 lm/W
10,000-hour life

Before You Start

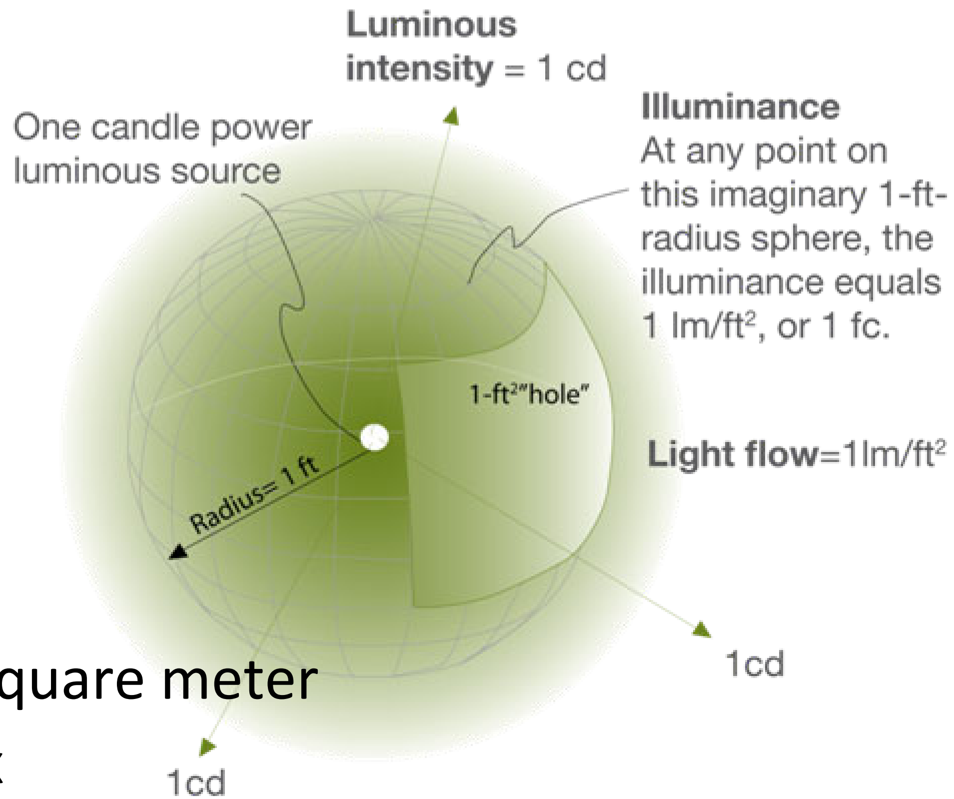
- Commercial buildings
  - Lighting accounts: 20-40%
  - Largest sources of internal heat gain
  - Lighting is one of the fastest developing energy-efficient technologies



Solar Spectrum (Source: E Source Lighting Atlas)

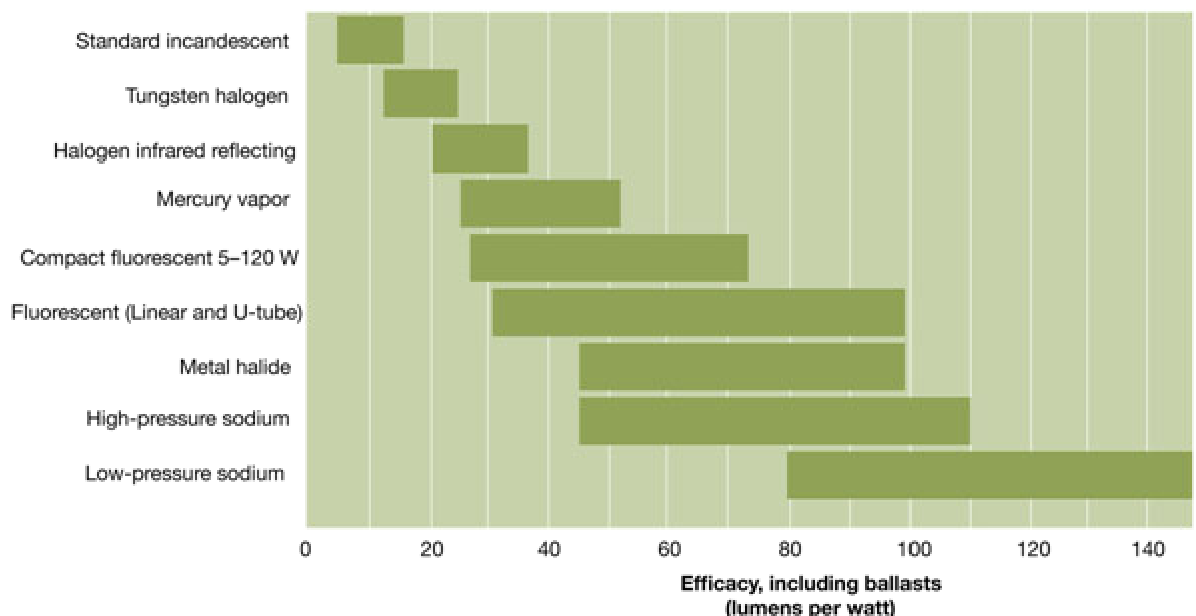
Lighting-Key Technical Terms

- Ballast
- Candela
- CRI
- CCT
- LPD
- Lux:
  - One lux = one lumen per square meter
  - One foot-candle=10.76 lux
- Lamp Efficacy
- T#: T5, T8, T12 fluorescent lamps



Basic Lighting Design Issues

- Daylighting integration
- Selection: How to illuminate a space efficiently
- Systems' interactive effect - Lighting (1 kWh reduces): Cooling (0.4 kWh saves)



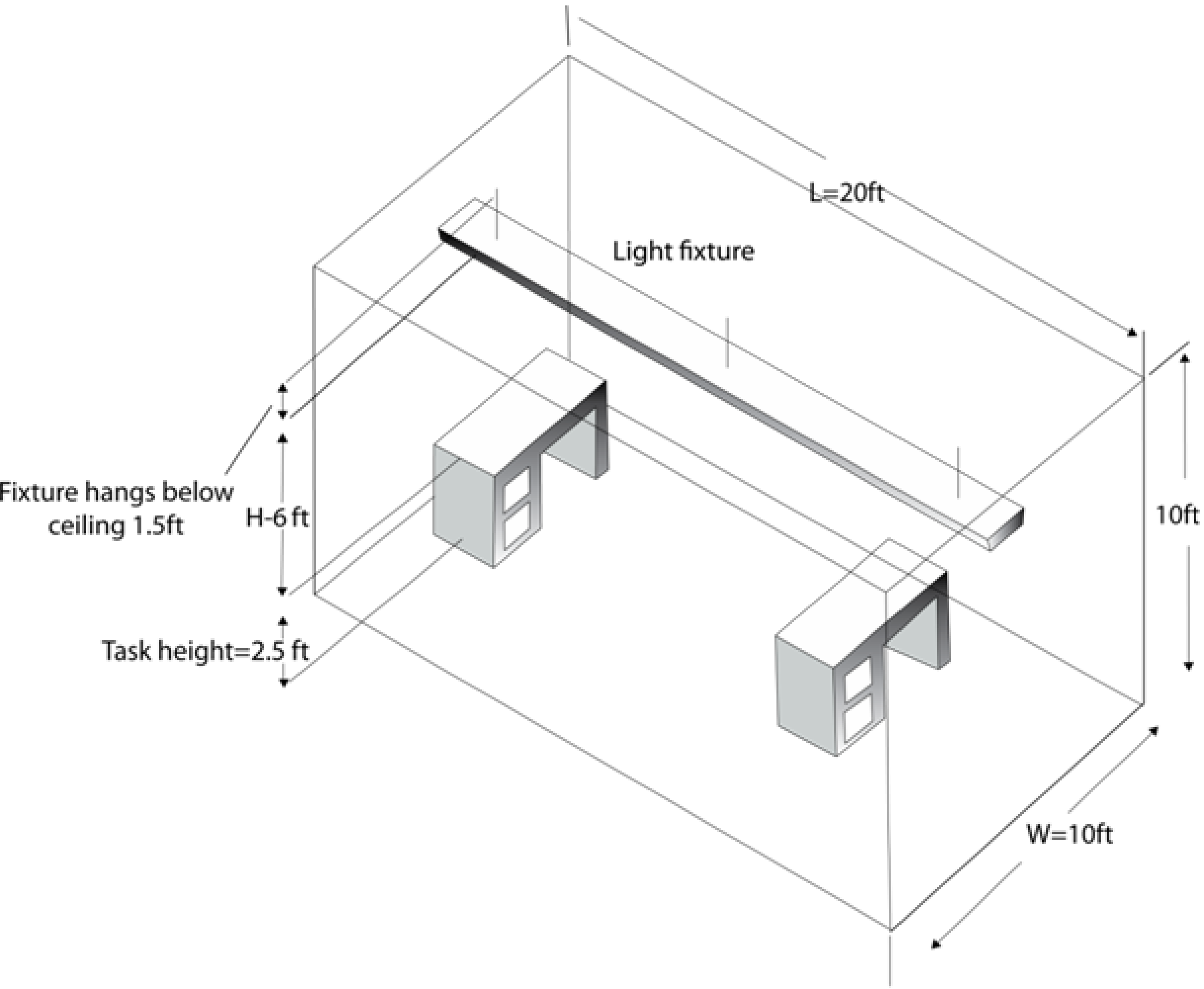
Basic Light Design Concept

- Manual calculations: general illuminance, or amount of light that reaches a surface
  - **The Zonal cavity or Lumen method:**
    - Considers several factors to determine type and number of fixtures = illuminance requirements of the space
  - **Room Cavity Ratio:**
    - RCR characterizes a room by shape
  - **Coefficient of Utilization:**
    - Measure of the fixture’s ability to distribute light work plane using the RCR value and the surface reflectance of wall, floor and ceiling

$$RCR = \frac{5(H)\,(L+W)}{L \text{ X } W}$$

$$= \frac{5(10-2.5-1.5)\,(20+10)}{20 \text{ X } 10} = 4.5$$

Illustrative Example



Room Dimensions and Fixture Location (Source: E Source Lighting Atlas)

Table 4: Typical Coefficient of Utilization (CU) Values

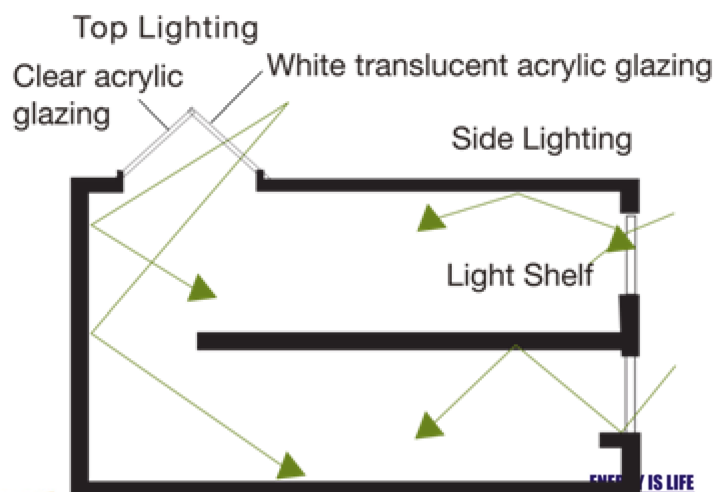
Reflectance (Wall)		50		30		10	
Reflectance (Ceiling)		80	50	80	50	80	50
Room Cavity Ratio (RCR)	1	67	56	65	53	53	51
	2	66	54	63	51	51	49
	3	65	52	61	50	50	48
	4	64	50	59	48	48	46
	5	63	48	57	46	46	44
	6	61	46	53	44	44	42
	7	59	43	51	42	42	40
	8	56	41	49	40	40	38
	9	54	40	47	38	38	36
	10	51	39	45	36	36	34

Calculate Average Illuminance Level

- The lumen method or zonal cavity calculation is a quick and simple technique for predicting the average illuminance level in a room. The calculations have simple input requirements:
  - Physical characteristics of the room, including length, width and height
  - Ceiling, wall and floor reflection (% of light reflected by the room surfaces)
  - Work plane height
  - Orthogonal distance between work plane and luminaries
  - Coefficient of Utilization (CU) for the luminaries
  - Number of lamps per luminaire and initial lumen output of each lamp
  - Light Loss Factors (LLFs)

Efficient Lighting Design

- Optimal solutions = Daylight + fixtures
- Skilled lighting designer = Quantity and quality of light + human factors = Specifying lighting systems
- Appropriate level of illumination
- Minimum input of energy
- Visual quality
- Switching or dimming
- Degree of automation



Simple daylighting Techniques (Source: E Source Lighting Atlas)

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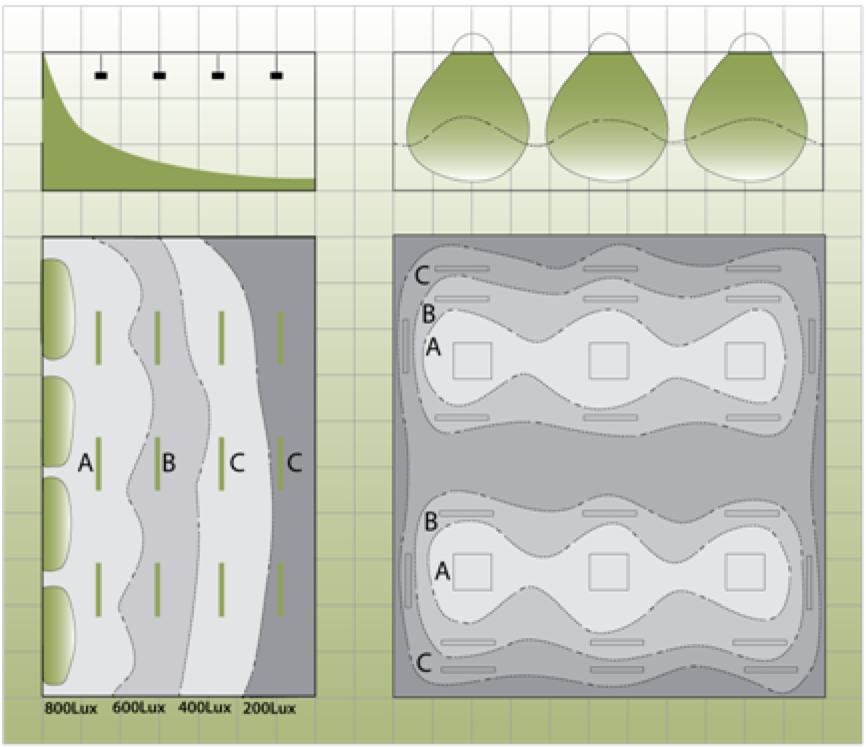
Illuminance Contours (Iso-Lux)



Align control circuits parallel to daylight contours when daylight levels vary across the space. In these plans and section of a sidelit office and skylit factory, "A" experiences the most daylight and is turned off or dimmed first "B" is controlled second, "C" receives the least daylight and is left at full power to maintain wall brightness. The office pendent direct-indirect luminaires are dimmed in response to daylight fry luminaires are bilevel switched. In the factory, the end luminaires on the B row are controlled with C circuit to maintain wall brightness.

Lighting Design Tools

- Lighting design is a challenge = worthy of computer modeling = Variables (different light sources + fixtures of varying efficiency and photometric + range of geometries + cost)
- Help designers in decision making = Compare lighting alternatives = ultimate design choice
- Optimized lighting design = Lighting quality + energy efficiency

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Impact of Dirt on Light Output

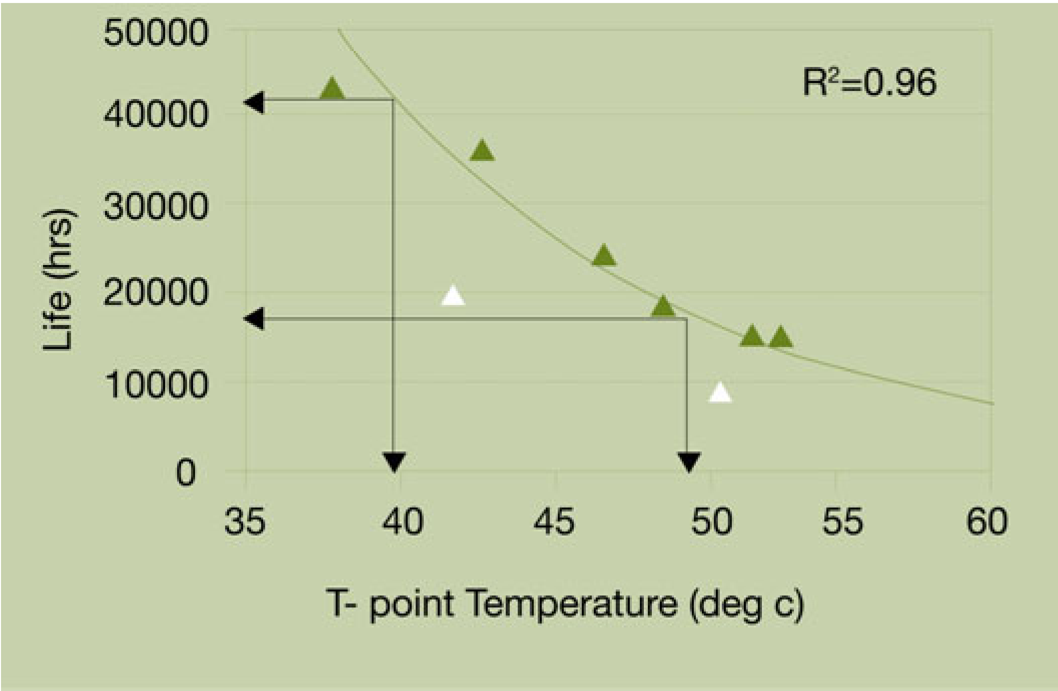
- Dirt condition:
  - Location
  - Poorly filtered air
- Can lose more than half their initial light output over a 3 year time
- Dirt is made up of several components
  - *Inert* dirt lands by gravity on non-vertical or textured surfaces
  - *Attracted* dirt adheres by electrostatic attraction
  - *Adhesive* dirt clings to surfaces by its stickiness

Light Loss Factor

- LLFs
  - **Light distribution:** affected by the color + reflectance of room surfaces + change in lighting output over time
  - **Lumen depreciation** data: lamp manufacturer + Dirt depreciation values: Graphs (IESNA)
- Above factors : gives "maintained foot-candle level."

Impact of Junction Temperature on Life of Bulb

- Recessed lighting fixtures:
  - Reduction in lamp life as a result of higher junction temperature



Effect of Junction Temperature on Life of LED Lamp (Source: Lighting Re- search Institute)

Lighting Technology

- Light distribution
- Lighting controls
- Lamp technologies
  - Incandescent lamps
  - Linear and compact fluorescent lamps (CFLs)
  - High intensity discharge lamps
  - Light-emitting diodes (LEDs)
  - Fixture & reflector

Technologies

- Magnetic and Electronic Ballasts characteristics for CFLs

Ballast Characteristics	Magnetic	Electronic
CFL base compatibility	Mostly two-pin	Mostly four-pin
Lamp/ballast efficacy	Low	High
Weight	High	Low
Noise level	Slight 120-Hz hum	Very quiet
Cost	Cheaper	Expensive
No. of lamps powered/ballast	1 or 2	1, 2, 3 or 4
Dimmability	No	Available
Universal input voltage	No	Available
Power Factor	0.4 to 0.7 (normal; > 0.9 (better)	0.4 to 0.7 (normal; > 0.9 (better)
Total Harmonic Distortion (%)	6-18 (normal); 15-27 (better)	75-200 (normal); 16-42 (better)

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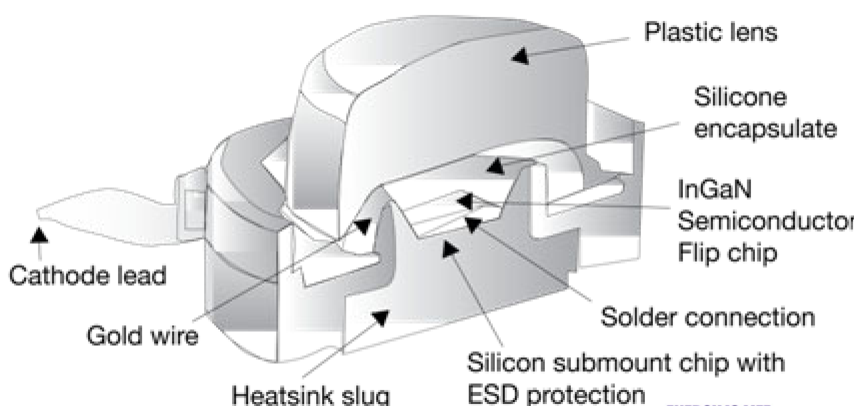
Different Light Sources

- Conventional incandescent
- Halogen incandescent
- Fluorescent tube light
- Compact fluorescent
- Mercury vapor
- Metal halide
- high- pressure sodium
- Low- pressure sodium



LED Operation (Source: E Source Lighting Atlas)

Comparative Characteristics of Different Light Sources

Characteristics	Conventional Incandescent	Fluorescent Tube Light	Mercury Vapor	Metal Halide	High-Pressure Sodium	Low-Pressure Sodium
Lumen Output (lumens)	10 to50,000	900 to 12,000	1,200 to 60,000	4,000 to 160,000	2,000 to 50,000	1,800 to 35,000
Efficacy (lumens per watt)	7 to 22	30 to 90	35 to 65	70 to 130	50 to 150	100 to 190
Color Rendering Index (CRI)	100	50 to 95	40 to 50	60 to 70	20 to 85	0 to 20
Power Factor	No problem.	Ballasts with high power factor are available. Some ballasts have low power factor.	Ballasts with high power factor are available. Some ballasts have low power factor.	Ballasts with high power factor are available. Some ballasts have low power factor.	Ballasts with-high power factor are available. Some ballasts have low power factor.	Ballasts with high power factor are available. Some ballasts have low power factor.

ECBC Compliant Lighting Design Strategy

- Mandatory requirements
  - Lighting control
  - Automatic lighting shutoff
    - Interior lighting systems for areas > 500 m2 + automatic control device
    - Independent program schedule : For areas > 2,500 m2 + not more than one floor
    - Occupancy sensors : within 30 minutes of an occupant leaving the space

Prescriptive Path

- Building area method
  - Determination of interior lighting power allowance (watts):
    - Step 1 = Allowed lighting power density for different building areas from Table 7.3.1
    - Step 2 = Calculate the gross lighted floor area
    - Step 3 = The interior lighting power allowance = Gross lighted floor area X allowed LPD (all building area types)

Table 7.3.1: Interior Lighting Power - Building Area Method

Building Area Type	LPD (W/m^2)	Building Area Type	LPD (W/m^2)
Automotive Facility	9.7	Multifamily Residential	7.5
Convention Center	12.9	Museum	11.8
Dining: Bar Lounge/Leisure	14.0	Office	10.8
Dining: Cafeteria/Fast Food	15.1	Parking Garage	3.2
Dining: Family	17.2	Performing Arts Theater	17.2
Dormitory/Hostel	10.8	Police/Fire Station	10.8
Gymnasium	11.8	Post Office/Town Hall/	11.8
Healthcare-Clinic	10.8	Religious Building	14.0
Hospital/Health Care	12.9	Retail/Mall	16.1
Hotel	10.8	School/University	12.9
Library	14.0	Sports Arena	11.8
Manufacturing Facility	14.0	Transportation	10.8
Motel	10.8	Warehouse	8.6
Motion Picture Theater	12.9	Workshop	15.1

Prescriptive Path

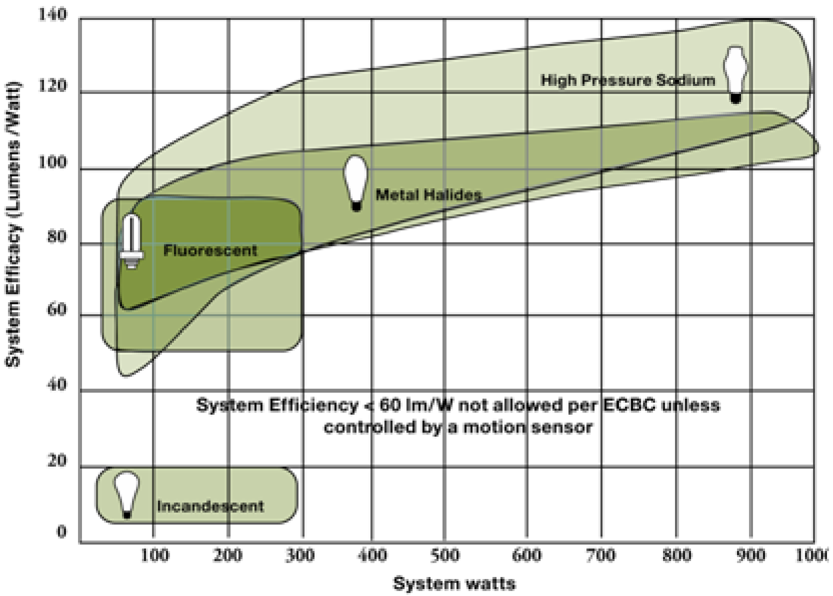
- Building space function method
  - Determination of interior lighting power allowance (watts):
    - Step 1 = Determine the allowed lighting power density from Table 7.3.2
    - Step 2 = Determine the gross interior floor area
      - » Exception: Retail spaces do not have to comply with the 80% partition height requirements
    - Step 3 = The Interior lighting power allowance = Gross lighted area of space X allowed LPD (all building space types)

Table 7.3.2 Interior Lighting Power - Building Space Function Method

Space Function	LPD (W/m^2)	Space Function	LPD (W/m^2)
Office-enclosed	11.8	Library	
Office-open plan	11.8	Card File & Cataloging	11.8
Conference/Meeting/Multipurpose	14.0	Stacks	18.3
Classroom/Lecture/Training	15.1	Reading Area	12.9
Lobby	14.0	Hospital	
For Hotel	11.8	Emergency	29.1
For Performing Arts Theater	35.5	Recovery	8.6
For Motion Picture Theater	11.8	Nurse Station	10.8
Audience/Seating Area	9.7	Exam Treatment	16.1
For Gymnasium	4.3	Pharmacy	12.9
For Convention Center	7.5	Operating Room	23.7
For Religious Buildings	18.3	Nursery	6.5
For Sports Arena	4.3	Medical Supply	15.1
For Performing Arts Theater	28.0	Physical Therapy	9.7
For Motion Picture Theater	12.9	Radiology	4.3

Table 7.4: Exterior Building Lighting Power Allowance

Exterior Lighting Applications	Power Limits
Building entrance (with canopy)	13 W/m^2 (1.3 W/ft^2) of canopied area
Building entrance (without canopy)	90 W/lin m (30 W/lin f) of door width
Building exit	60 W/lin m (20 W/lin f) of door width
Building facades	2 W/m^2 (0.2 W/ft^2) of vertical facade area



Exterior Grounds Lighting and specific Technologies (Source: Adapted from ASHRAE/ IESNA Standard 90.1-1999)

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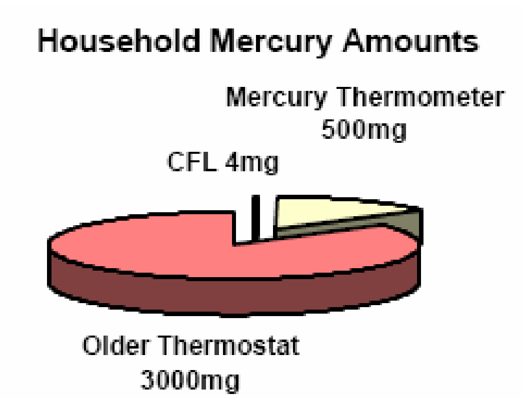
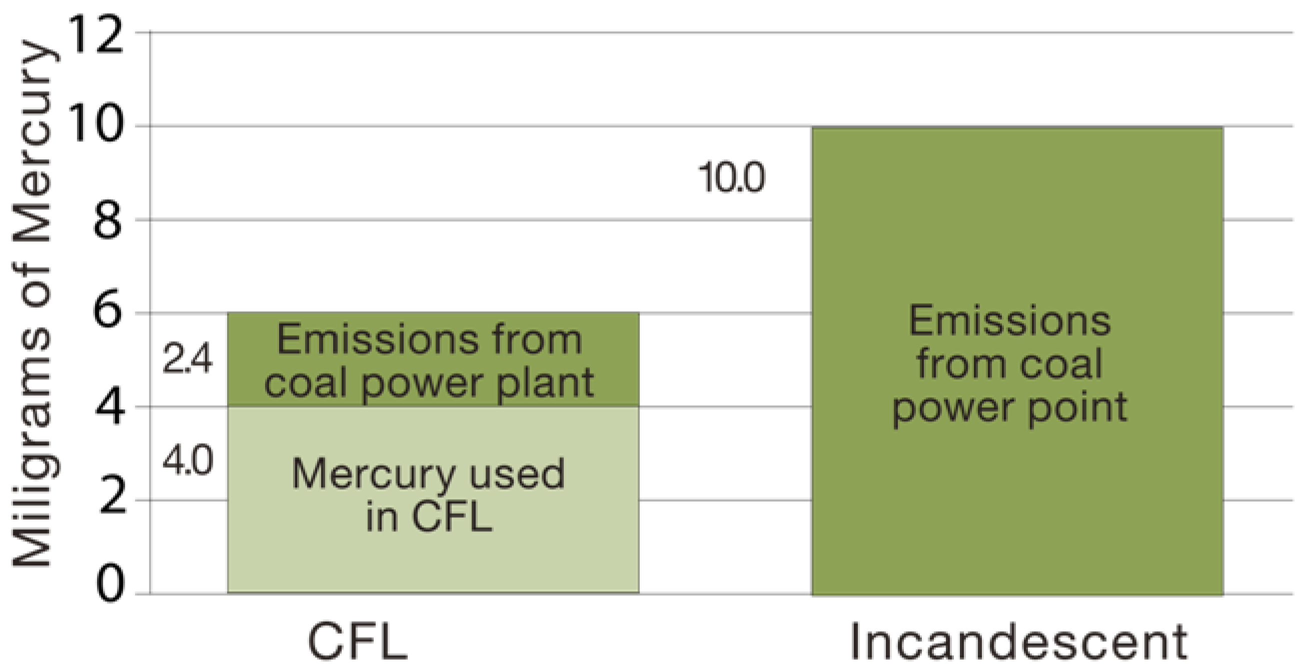
Exploding Myth About Mercury Use in CFLs

- CFLs responsible for less Mercury than Incandescent light bulbs
  - CFL uses 75% less energy than an incandescent light bulb and lasts at least 6 times longer





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ECO-III Project Partners - Key to Success

- **Public Sector Partners**
  - Bureau of Energy Efficiency
  - Reserve Bank of India, CPWD
  - GEDA and PEDA
  - Gujarat Urban Development Company
  - US DOS, US DOE, LBNL, EVO
  - World Bank
- **Industry Associations**
  - CII Green Business Center
  - ISHRAE
  - NASSCOM
  - GESCSL, Vatva Industrial Estate
  - Glazing Association of India
- **Private Sector Partners**
  - Alliance to Save Energy, NPC, DSCL Energy Services, CEPT, Conzerv, NISST, See-Tech
  - Infosys
  - DLF
  - E-Source, Colorado, USA
  - DesignBuilder, UK
- **Academic Institutions**
  - 20 Architecture/Engineering Colleges
    - CEPT, IIT-KGP, IIT-R, IIIT, MNIT
  - IIM Ahmedabad
  - Technical University of Vienna

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