

ENERGY EFFICIENT LIGHTING

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- Basics of Illumination
- Types of light source, lighting
- Comparison of commercial lamps
- Energy efficient lighting
 - ▣ More light from less power
 - ▣ Lighting controls
 - ▣ Energy efficiency in street lights
 - Centralize and Decentralized control
- Conclusion

Why study Light?

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- Light is an extremely efficient way of altering perception
- Improve weight gain in premature infants.
- Increase the length and quality of sleep.
- *“Some researchers believe that even very low levels of blue light during sleep might weaken the immune system and have serious negative implications for health.”*
- Bad lighting can ruin perfectly good design
- Light can alleviate seasonal depression.

Consumption in India

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- One-fifth of electricity consumption in India is through lighting
- Lighting contributes significantly to peak load
- A large portion of total lighting is used in inefficient technologies
- About 400 million light points in India today are lighted by incandescent bulbs; their replacement by CFLs would lead to a reduction of over 10,000 MW in electricity demand.
- Bachat Lamp Yojana – CFL @ Rs. 15 per piece – rest of money is claimed through CDM

Why Energy Efficiency in Lighting?

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- High and rising energy prices
- Change in Global Climate
- Exhaustion of Non Renewable Sources for electricity generation
- Leads to reduction of investment for expansion of electric power sector

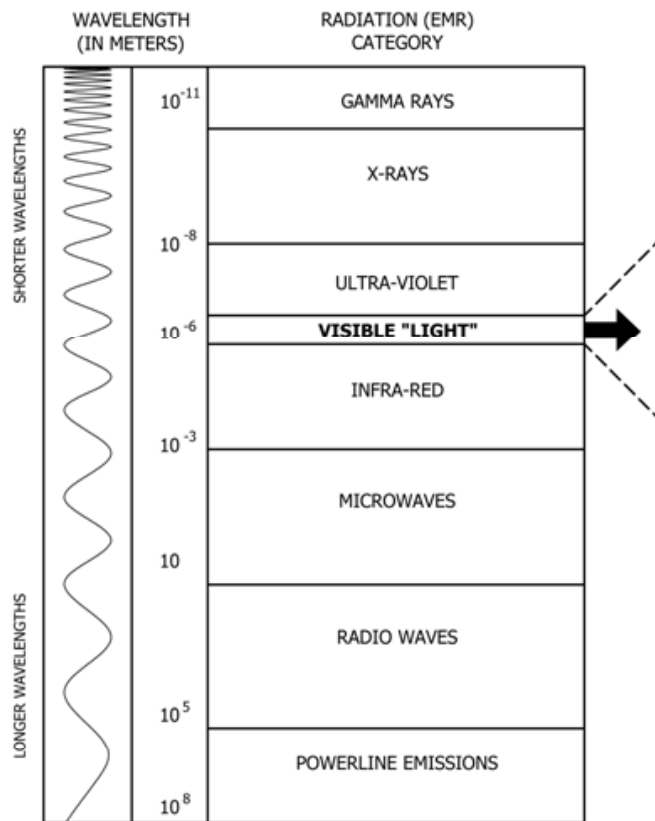
Physics of Light

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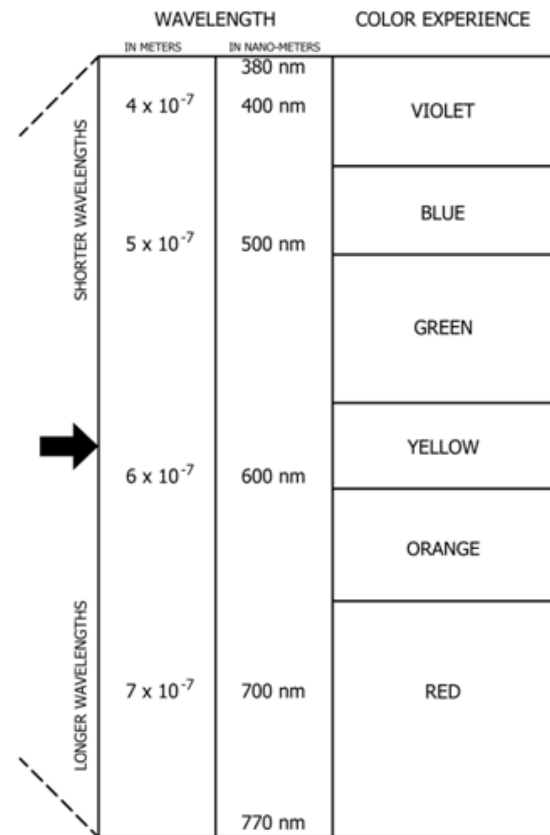
- Light is a member of a large family called electromagnetic radiation (EMR)
- Heat, light, x-rays, microwaves, U.V. are all examples of EMR
- EMR travels with speed of light and has a wide spectrum of wavelength
- The visible spectrum includes radiation from 380 Nm to 750 Nm in wave length
- Visible light consist of violet, indigo, blue, green, yellow, orange

Spectrum of EMR-Light

COMPLETE ELECTRO-MAGNETIC RADIATION SPECTRUM

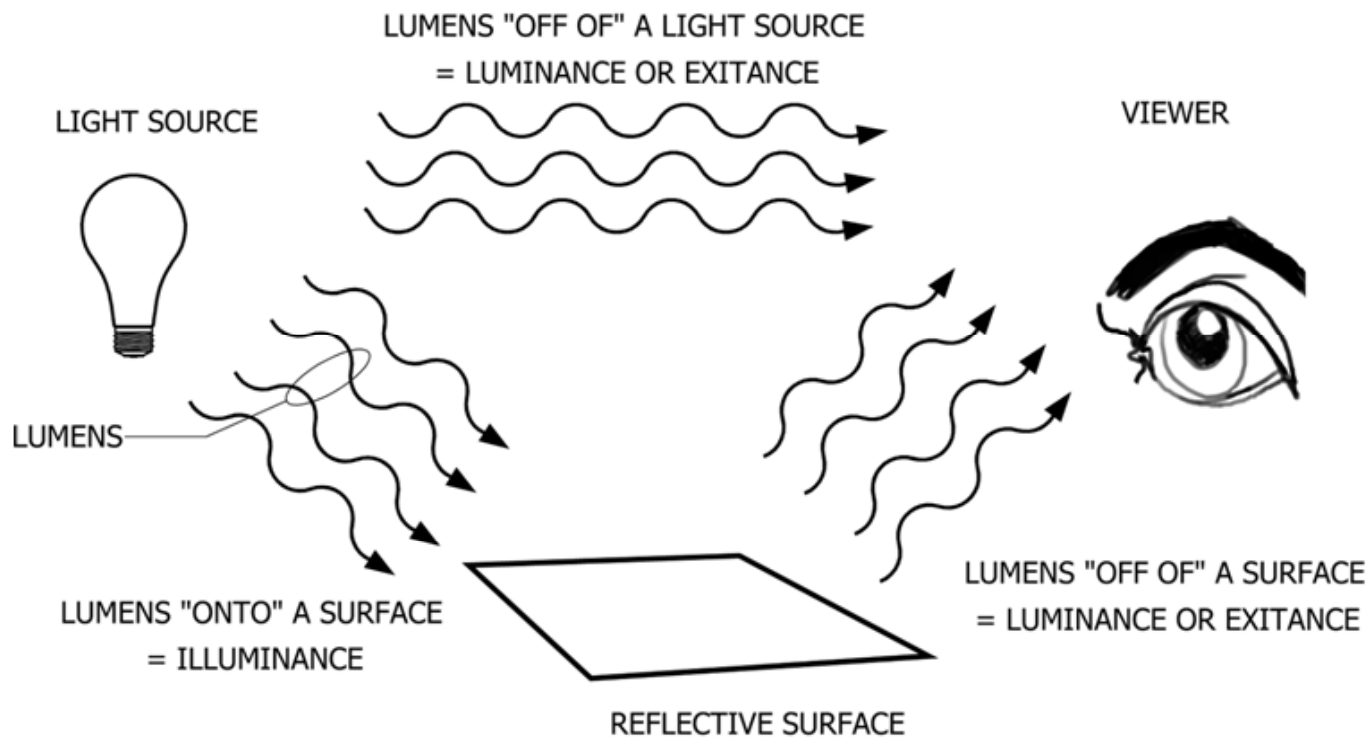


THE VISIBLE SPECTRUM



Terminology in Lighting

3 INTERACTIONS OF LIGHT



Lumens, Efficacy

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- Luminous flux: It is measure of perceived power of light. Lumen is standard unit for luminous flux.
- Luminous flux incident on a surface per unit area is called Illuminance and lux is the SI unit. $1 \text{ lux} = 1 \text{ lm/m}^2$
- How well a source provides a visible light for a given amount of power is generally termed as Efficacy
- Luminous efficacy of a source (LES) is the ratio of lumens per unit input power (lm/W). Input power is generally assumed to be electricity.

Color Rendering Index

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- “Effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant”, *International Commission on Illumination (CIE)*
- Ability of a light source to accurately reproduce colors of objects in comparison with an ideal source
- Good - Day light, incandescent, metal halide, good LED's (80-100)
- Bad - Low pressure sodium lamp has poor color rendering (0-10)
- Average - High pressure sodium has average color rendering (20-60)

Color Temperature

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- The temperature at which a heated black body radiator matches the color of light source
- Usually measured in kelvin (K)
- Higher color temperatures (5000 K or more) are "cool" (green–blue) colors, and lower color temperatures (2700–3000 K) "warm" (yellow–red) colors.
- Correlated color temperature in case of CFL as there is no physical heating of a black body

Types of Lighting

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- Incandescent lamp
- Gas Discharge lamp
 - ▣ Low pressure discharge (Fluorescent, LPSV)
 - ▣ High pressure discharge (*metal halide, HPSV, high pressure mercury vapor*), HID family
- Solid State Lighting
 - ▣ Light Emitting Diode (LED)
 - ▣ Organic Light emitting diode (OLED)

Incandescent Lamp

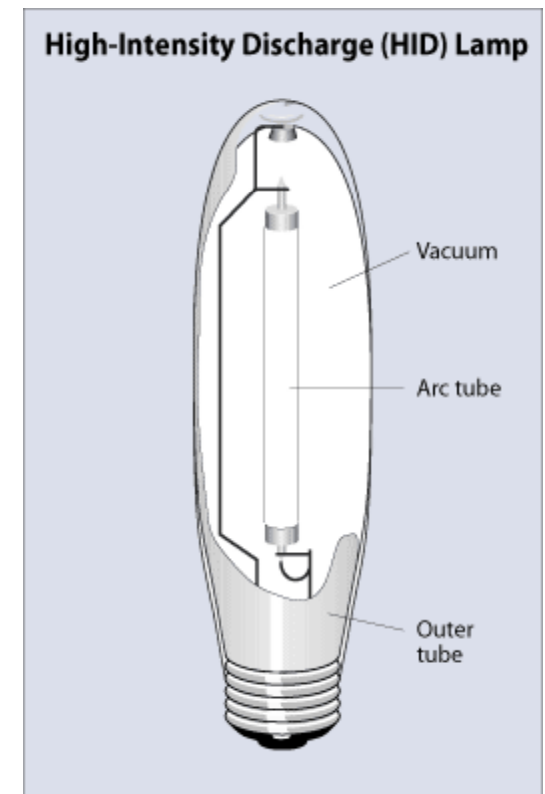
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- It is oldest and common type of lamp
- Light up instantly and provide warm light
- Do not need a ballast and cheaper
- Light is produced when coil of Tungsten is heated by passing electric current
- Most of the power is lost in heat
- Less Efficacy and lowest average life of (2000 hours)
- Very good Color Rendering Index (~ 100)
- Standard incandescent, tungsten halogen and reflector are three common types

High Intensity Discharge

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- An electric arc between two electrodes is used to produce intensely bright light
- Mercury, sodium or metal halide act as the conductor
- HID have highest efficacy and longest life
- They are used generally for outdoor purpose and large indoor arena
- Ballast needs time to establish arc and hence they take 10 minutes (max) when first turned on



Comparing Commercial Lamps

	Incandescent		Fluorescent		HID	
	Standard	Halogen	Full-Size or U-bent	Compact	Metal Halide	High-Pressure Sodium
Wattage	3-1,500	10-1,500	4-215	5-58	32-2,000	35-1,000
Lamp Efficacy	6-24	8-35	26-105	28-84	50-110	50-120
Average Rated Life (hours)	750-2,000	2,000-4,000	7,500-24,000	10,000-20,000	6,000-20,000	16,000-24,000
CRI (%)	99	99	49-96	82-86	65-96	21-65
Start-to-Full Brightness	immediate	immediate	0-5 seconds	0-5 minutes	1-15 minutes	4-6 minutes
Re-Strike Time	immediate	immediate	immediate	immediate	2-20 minutes	1 minute
Lumen Maintenance	very good	excellent	very good	good	fair/good	very good

Energy Efficiency Techniques

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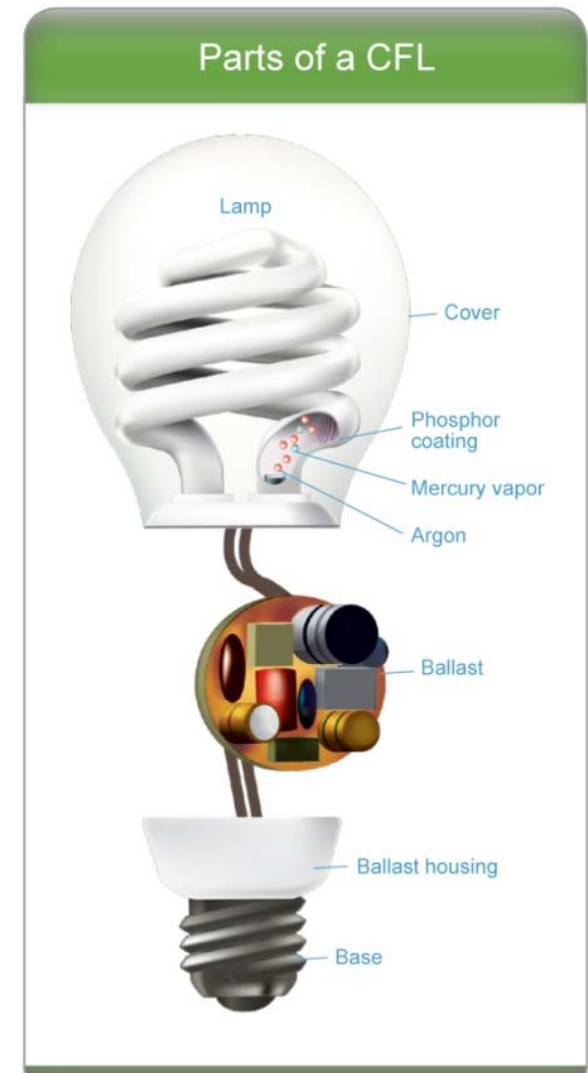
- Use of Day light, turn off the lights when not required
- Proper maintenance of lamps
- Replacement with energy efficient lamps
- Incorporate proper lighting controls
- Use of electronic chokes instead of conventional electromagnetic ballasts
- Use of dimming controls
- Use of 28 watt T5 instead of 40 watt standard FTL

More Light from Less Power - CFL

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Compact Fluorescent Lamp

- ❑ Electric current is passed through a tube containing Argon (inert gas) and Mercury Vapor
- ❑ This emits UV light which strikes the fluorescent coating (phosphor) inside of the tube and finally emits visible light
- ❑ CFL needs more energy during start and consumes less energy later



How to choose in CFL?

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Incandescent bulb (W)	Minimum Light Output (lumens)	CFL (W)
40	450	9 – 13
60	800	13 – 15
75	1100	18 – 25
100	1600	23 – 30
150	2600	30 – 52

Type	Purpose	Temperature
Warm White and Soft White	Standard replacement of Incandescent Bulb	2700 – 3000 K
Cool White and Bright White	Good for Kitchen and Work Spaces	3500 – 4100 K
Natural or Day light	Reading	5000 – 6500 K

How to choose in CFL?

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	Table/ Floor Lamp	Pendant Fixture	Ceiling Fixture	Ceiling Fan	Wall Sconces	Track Lighting	Outdoor Covered
Spiral	☺		☺	☺	☺		
Covered A shape	☺	☺		☺			
Globe		☺					
Tube	☺		☺		☺		
Candle					☺		
Indoor Reflector						☺	
Outdoor Reflector							☺

More Light from Less Power - LED

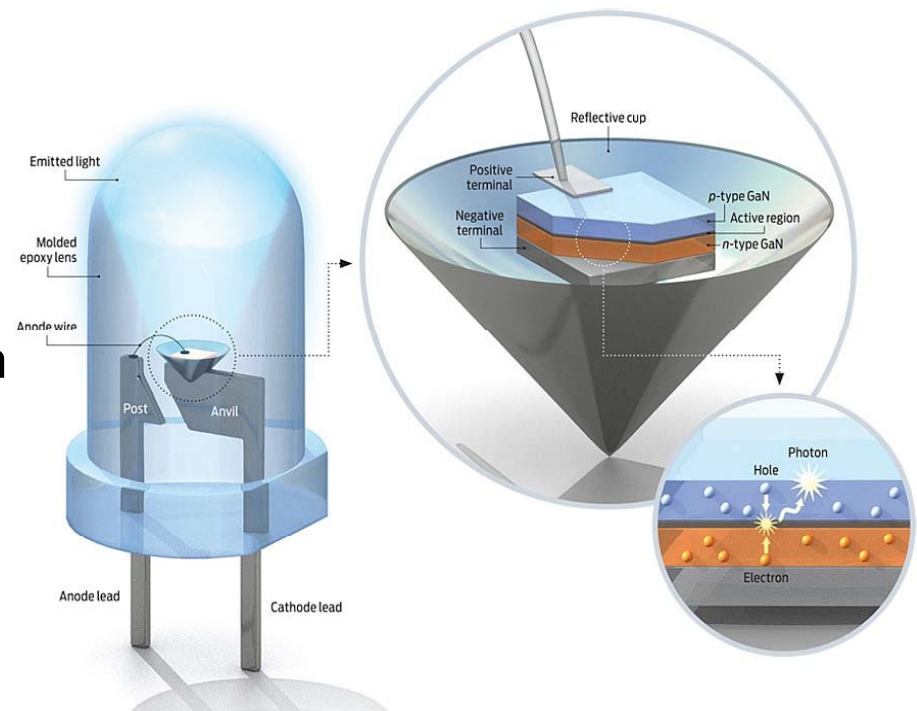
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- It is essentially a semi conductor diode
- It consists of a chip of semiconducting material treated to create a structure called a p-n (positive-negative) junction
- When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon (light).
- The specific wavelength or color emitted by the LED depends on the materials used to make the diode.

More Light from Less Power - LED

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- Red LEDs are based on aluminum gallium arsenide (AlGaAs).
- Blue LEDs are made from indium gallium nitride (InGaN)
- Green from aluminum gallium phosphide (AlGaP).
- "White" light is created by combining the light from red, green, and blue (RGB) LEDs
- White - by coating a blue LED with yellow phosphor.



More Light from Less Power - LED

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- No Mercury
- CRI of 92, some LED lights are dimmable
- Long Life (> 50000 hrs), high efficacy (102 lm/W)
- They generally consume 80% less power than incandescent lamp and 50% of CFL.
- 12W LED can replace 65W Incandescent

Lighting Controls

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- Types
 - ▣ Infrared sensors
 - ▣ Motion sensors
 - ▣ Automatic timers
 - ▣ Dimmers
- SCADA, GSM/GPRS based centralized control system for street light
- Save energy by on/off and dimming
- Up to 40% energy saving in street lights without replacing existing fixtures

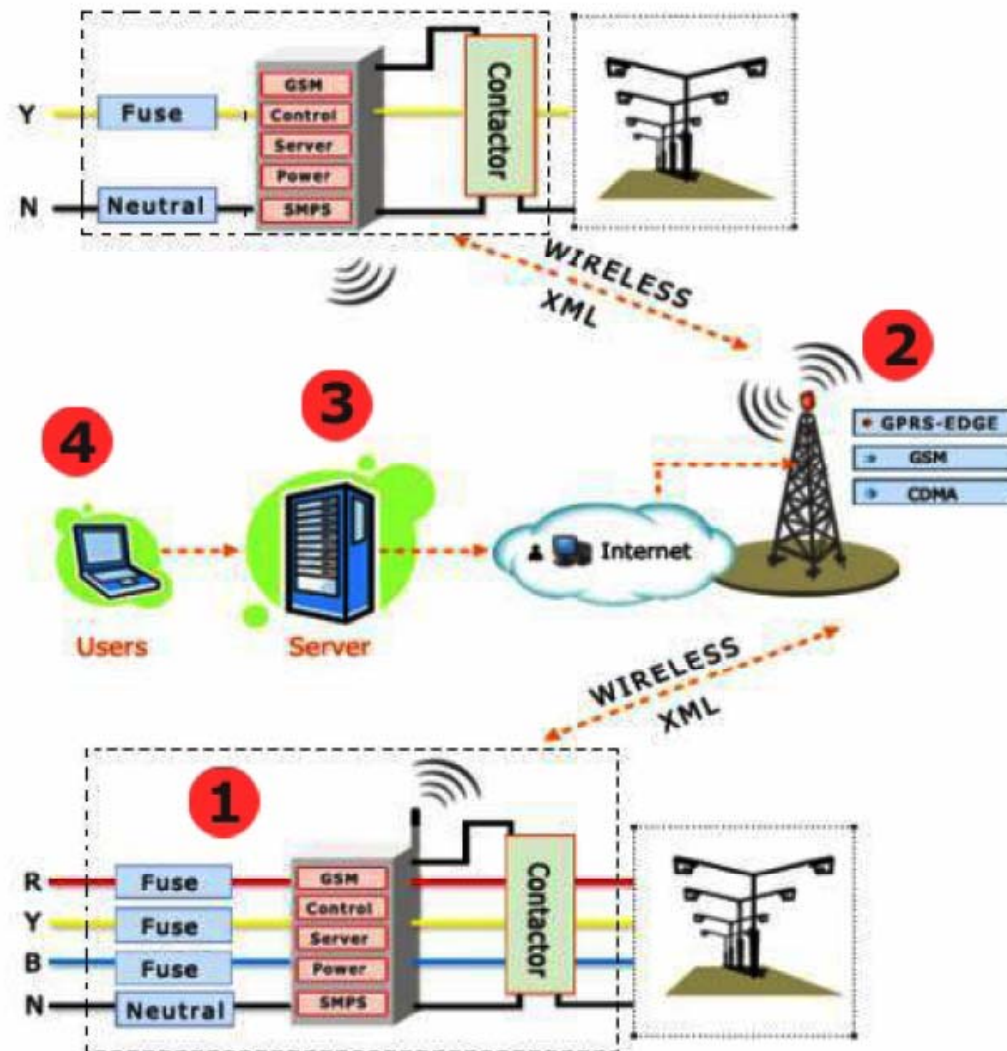
Energy Efficiency in Street Light

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- ❑ Street light contribute to peak power consumption
- ❑ Replacement with high efficient bulbs and fixtures
- ❑ Electronic Timer
- ❑ Nature Switch
- ❑ Dimmable ballast or Magic Box
- ❑ Voltage regulator
- ❑ Centralized control using GSM/SCADA
- ❑ Regular maintenance of fixtures
- ❑ Power factor improvement techniques

Street light control system - Architecture

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Centralized control of street lights

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- Load balancing information (voltage, current & pf)
- Exact identification of failure (Fuse, CB, Power failure status)
- Lamps glowing and non glowing information
- Theft and functioning of switch gear
- Twilight based
- Alternate lighting pattern is possible
- Dimming can be incorporated
- Communication via SMS/GPRS/EDGE/Radio/CDMA
- Number of hours of glowing, complete MIS

Energy Efficiency/Saving projects

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- Does street light required such complex architecture? What will be the implementation cost?
- Energy Saving Company (ESCO) – BEE listed
- Investment is done by ESCO and financial risk to the municipal corporation or government is low
- Return on Investment is obtained to ESCO based on savings
- Sharing of profits on public private partnership (PPP) mode
- CDM benefits

Conclusions

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- Energy efficiency is a really smart way to reduce demand on power system and reduce CO₂ emissions quickly
- Use day light where ever possible
- Reduce the excess light level to the required level
- Common lamps especially incandescent and CFL loose their output over time and hence needs replacement
- Consider group re-lamping to save labor

Conclusions

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- Re-lamping - Use high efficiency ballast and lamps
- Perform simple maintenance which will improve illumination
- New buildings should be designed in such a way that maximum day light is utilized
- Use better luminaries and improved controls

Thank You

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Suryanarayana Doolla, CEP Course on Energy Management, IIT Bombay, 2009