ENERGY EFFICIENT LIGHTING

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Content

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

Why study Light?

- 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

- 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

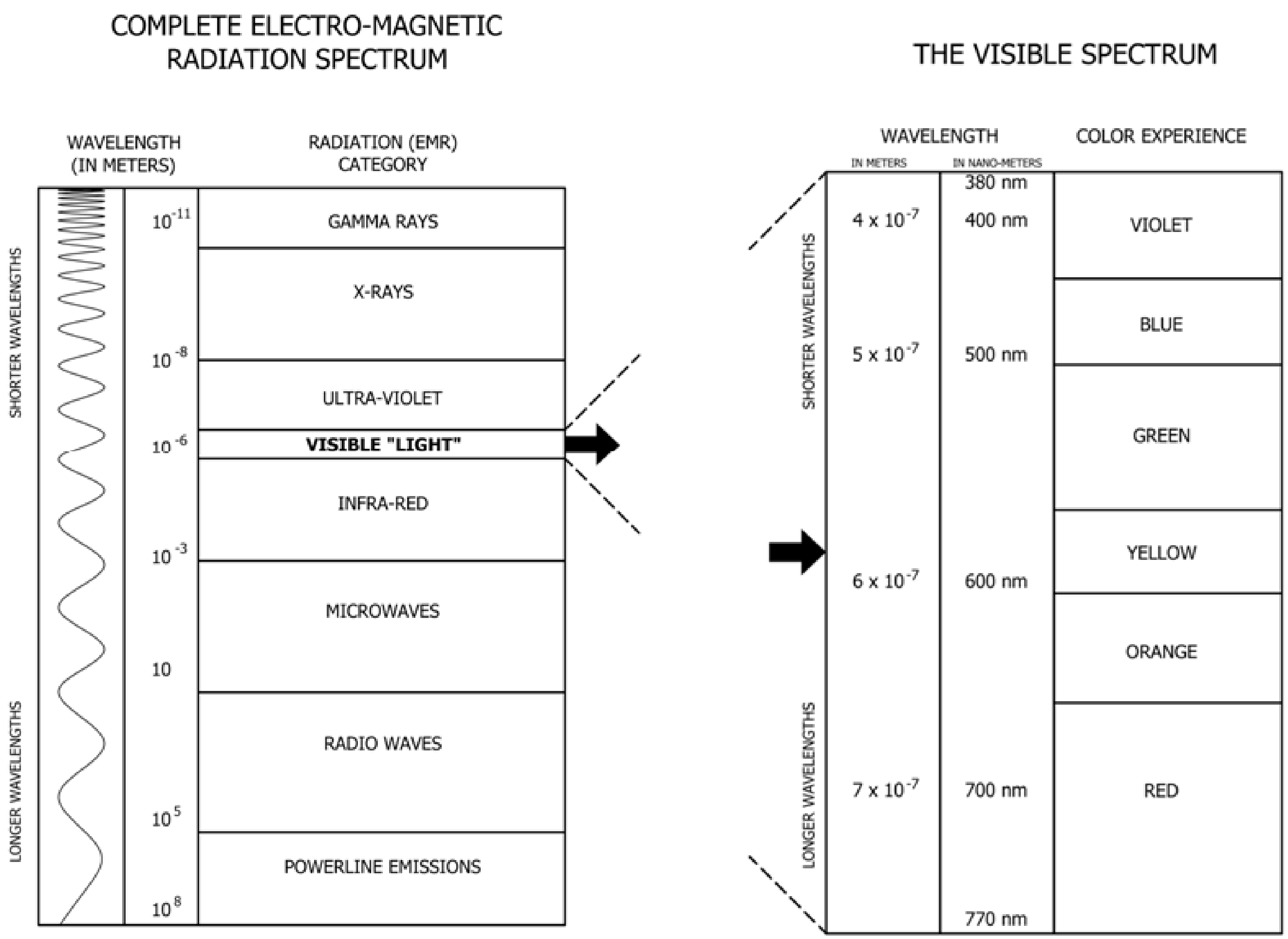
Why Energy Efficiency in Lighting?

- 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

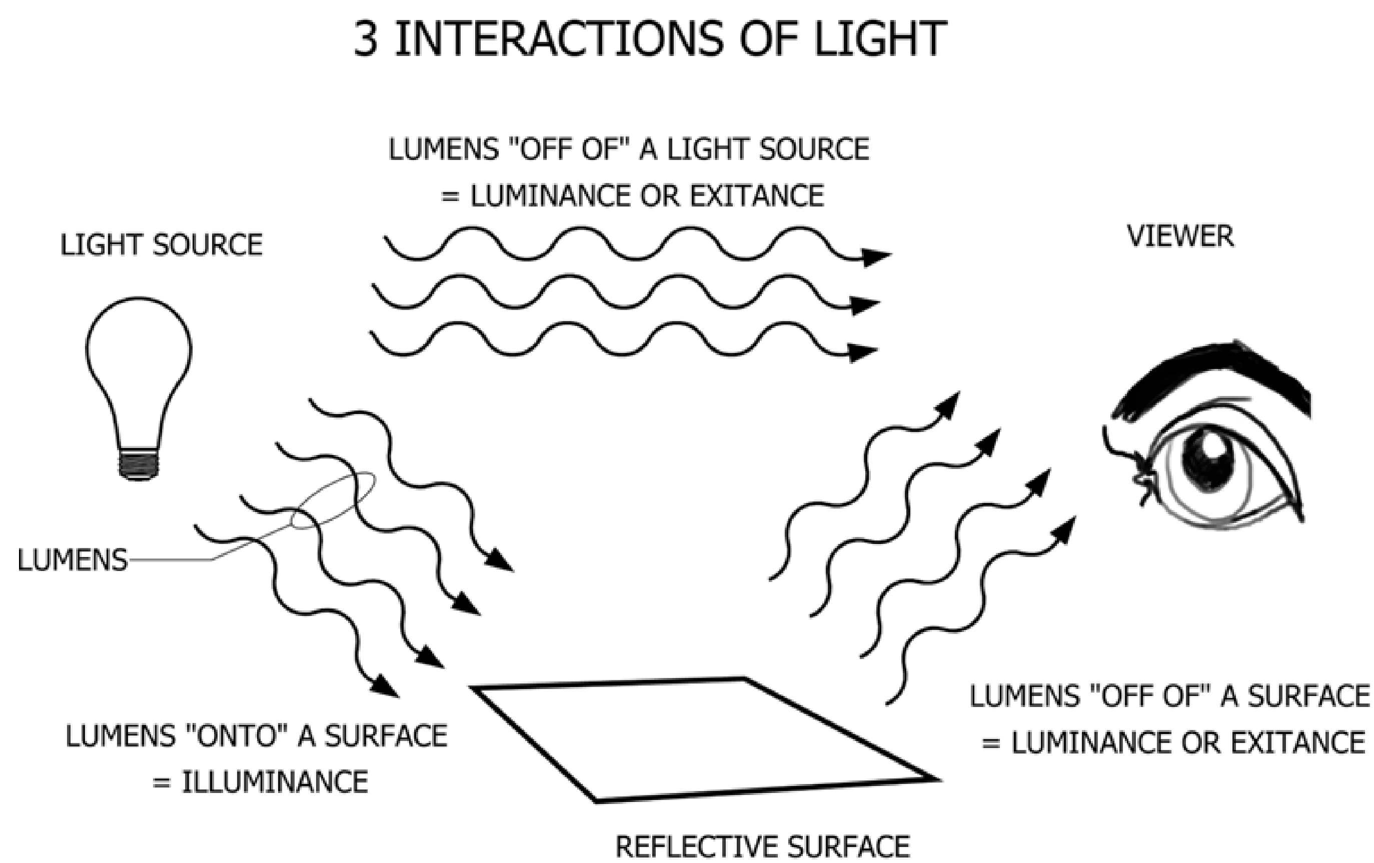
- Light is a member of a large family called electromagnetic radiation (EMR)
- Heat, light, x-rays, microwaves, U.V. are all examples of EMR
- EMR travels with speed of light and has a wide spectrum of wavelength
- The visible spectrum includes radiation from 380 Nm to 750 Nm in wave length
- Visible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

Spectrum of EMR-Light



Source: www.thelightingtextbook.com

Terminology in Lighting



Source: www.thelightingtextbook.com

Color Rendering Index

- “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

- 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

Lumens, Efficacy

- 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 lux= 1lm/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.

Efficacy – Redefined??

- Human vision is enabled by three modes
- Photopic vision: Vision under well-lit conditions, which provides for color perception, and which functions primarily due to cone cells in the eye.
- Scotopic vision: Monochromatic vision in very low light, which functions primarily due to rod cells in the eye.
- Mesopic vision: A combination of photopic vision and scotopic vision in low lighting, which functions due to a combination of rod and cone cells in the eye.

S/P Ratio

- The rods are highly effective at low light levels
- Cones are effective at daylight.
- Under both conditions the eye responds dynamically and with different sensitivities and varying spectral compositions.
- Daylight sensitivity is called Photopic, using the cone s and the peak sensitivity is at 555 nm .

S/P Ratio

- Night vision sensitivity is called Scotopic and makes use of therods in the eye.
- The rods peak sensitivity is at 507 nm and is about 2.7x more than the photopic sensitivity.
- The S/P ratio indicates for a lamp how much more the efficient the lamp is under night vision conditions than the photopic standard.
  - MOVE -Mesopic Optimisationof Visual Efficiency
  - CIE TC1-58 “Visual performance in mesopic range”

Problem with Meters?

- Suitable methods to evaluate the visual effectiveness of lighting products and installations in the mesopic region have not been available.
- The use of mesopic dimensioning changes the luminous output and consequently the luminous efficacy orders of lamps.

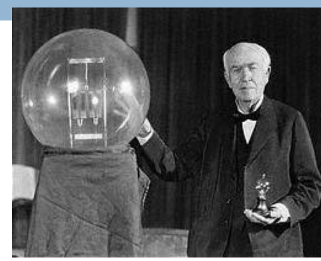
Problem with Meters?

- Many of the 'white light' sources currently used for applications such as road lighting have S/P-ratios between about 0.65 (high pressure sodium, for example) and 2.50 (certain metal halide lamps, for example).
- The S/P-ratios of warm white LEDs are around 1.15 and those of cool white LEDs around 2.15. The use of the new mesopic system to calculate the effective luminance of these white light sources results in significant changes in their apparent efficacy.

Process involved in Artificial lighting

- Incandescence
- Luminescence
- Fluorescence
- Phosphorescence
- ***Good efficient lighting is obtained by combining Luminescence and Fluorescence.***

Types of Lighting



- Incandescent lamp
- Gas Discharge lamp
  - Low pressure discharge (Fluorescent, CFL, LPSV)
  - High pressure discharge *(metal halide, HPSV, high pressure mercury vapor)*, HID family

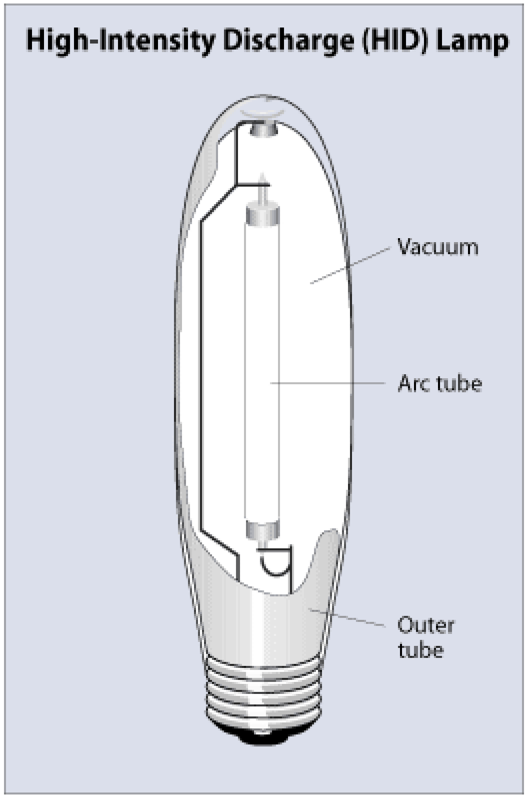
- Solid State Lighting
  - Light Emitting Diode (LED)
  - Organic Light emitting diode (OLED)

Incandescent Lamp

- 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 (15-20lm/watt) and lowest average life of (1000-3000 hours)
- Very good Color Rendering Index (~100)
- Standard incandescent, tungsten halogen and reflector are three common types

High Intensity Discharge

- 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 (60-150 lm/watt, 8000-40000 hrs)
- 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



Source: http://www.energysavers.gov

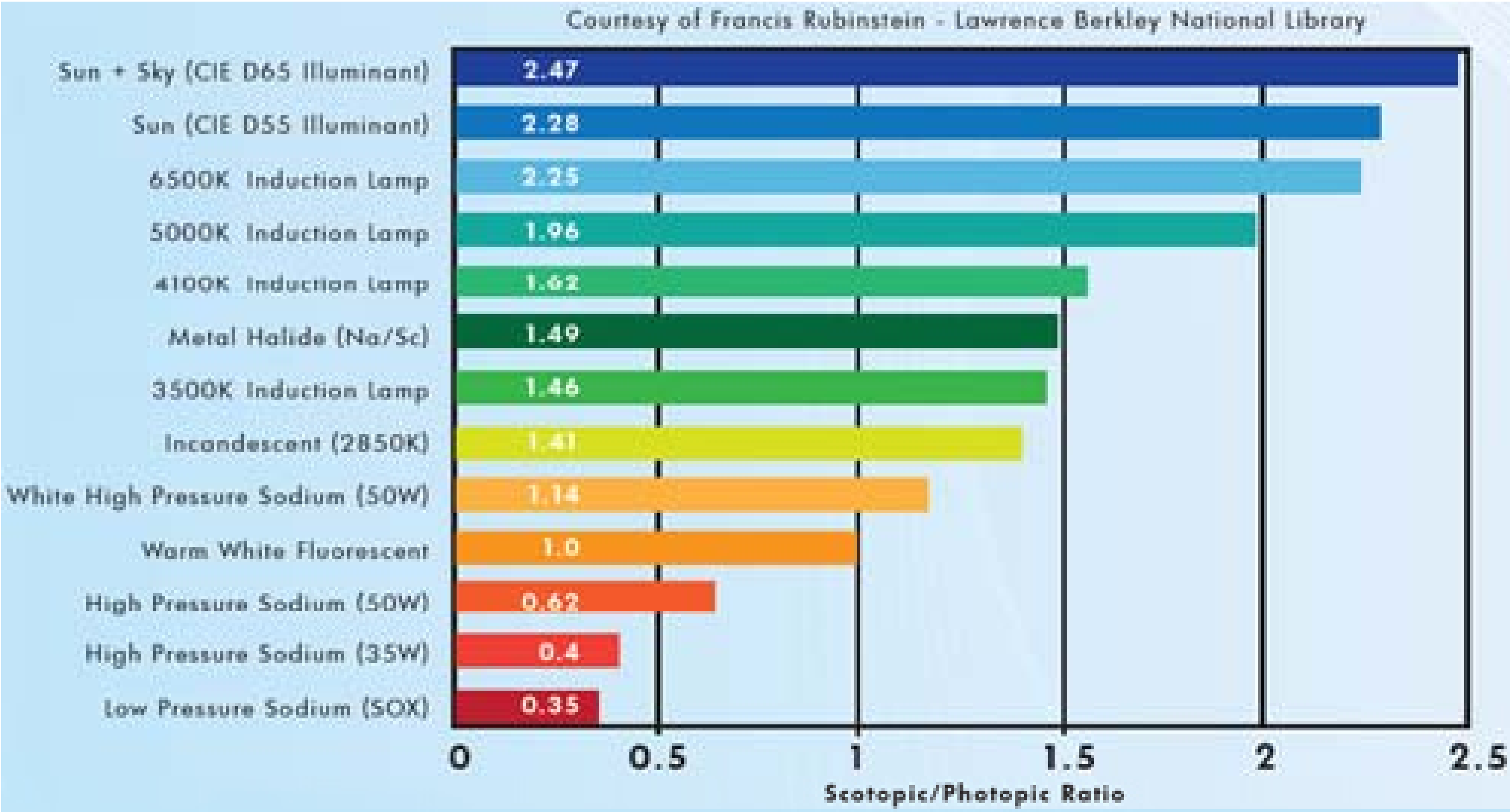
Comparing Commercial Lamps

	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)	1000-3,000	2,000-4,000	7,500-24,000	10,000-20,000	6,000-20,000	16,000-35,000
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

Source: American Council for Energy Efficient Economy

Induction Lamp

- Electronic ballast
  - High frequency electro magnetic field in the magnetic ferrite ring coils
  - These rings create an electromagnetic field inside the lamp's glass tube (sealed)
- Electrons discharged collide with mercury atoms inside the tube and become excited
  - Electrons give off energy in the form of invisible UV light.
- Passes through a phosphor coating on the inside surface of the tube – Visible light



S/P Ratio Example

Metal Halide - 400 watt has manufacturers rating of 56.9 lumens per watt . This results in 400x56.9=22,760 lumens x1.49 (S/P ratio) =33,912 Visually Effective Lumens.

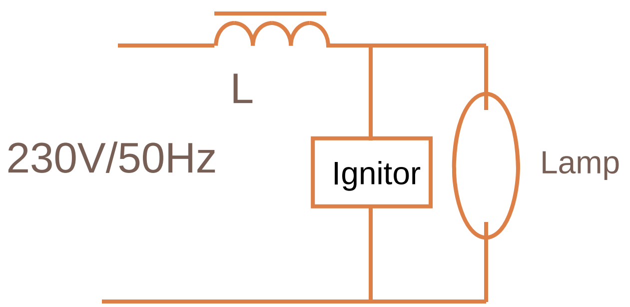
Induction - 200 watt has a manufacturers rating of 80 lumens per watt . This results in 200x80=16,000 lumens x2.25 (S/P ratio) =36,000 Visually Effective Lumens.

Energy Efficiency Techniques

- 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

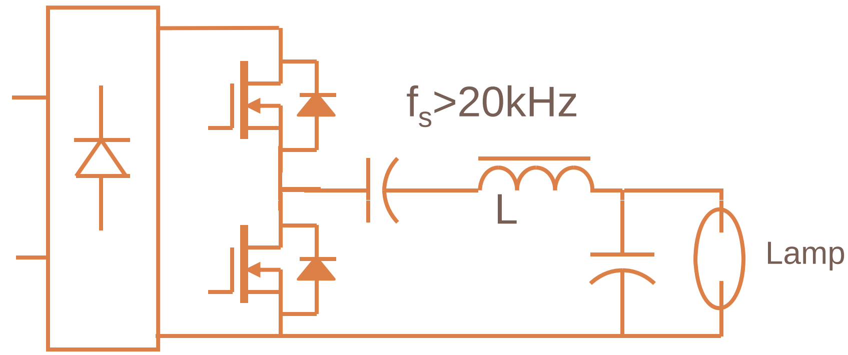
From Magnetic to Electronic Ballast

Magnetic Ballast



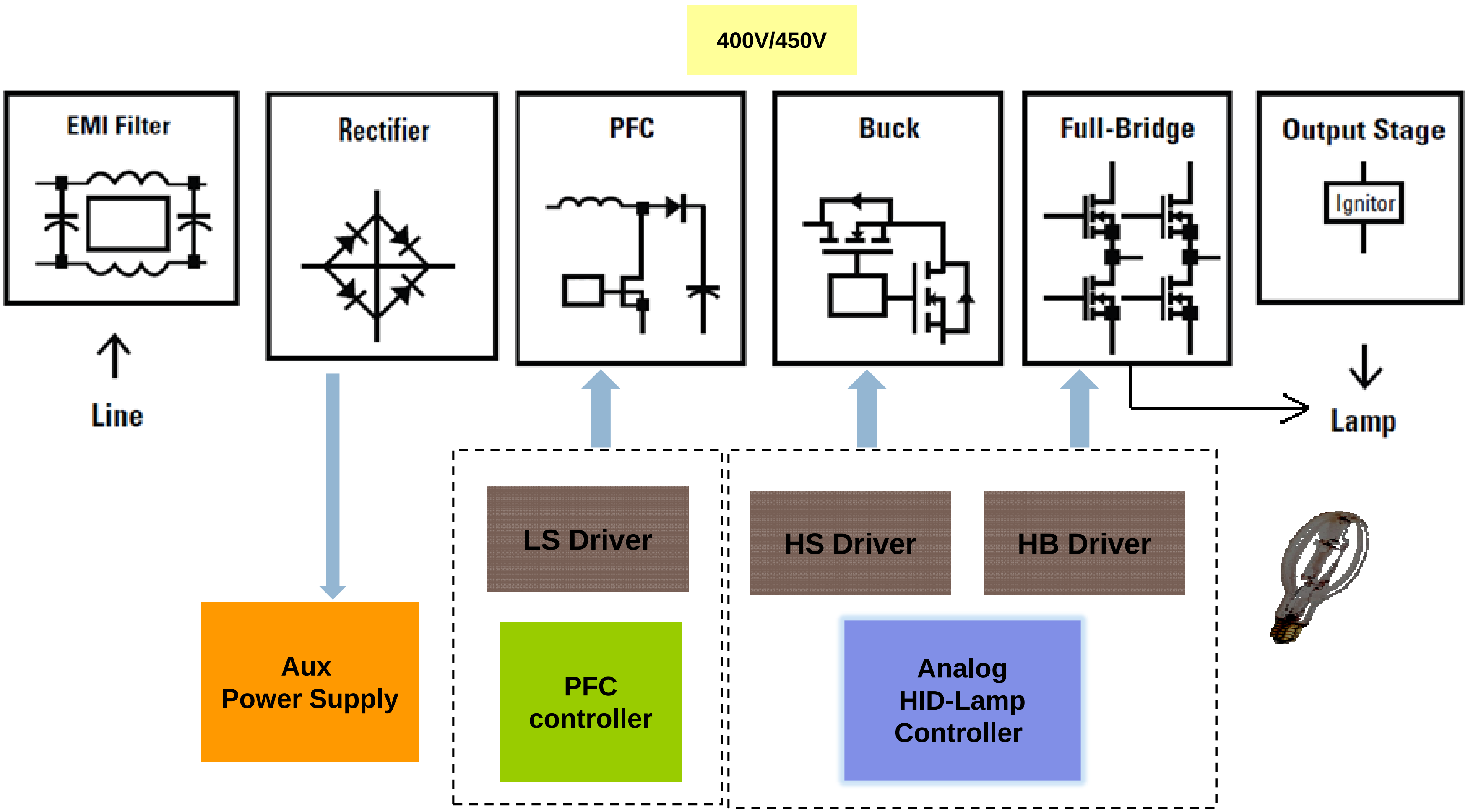
- Simple, low cost, high reliability
- Large and heavy
- External ignitor
- Re-ignition causes line frequency flickering
- No lamp power regulation

HF Electronic Ballast

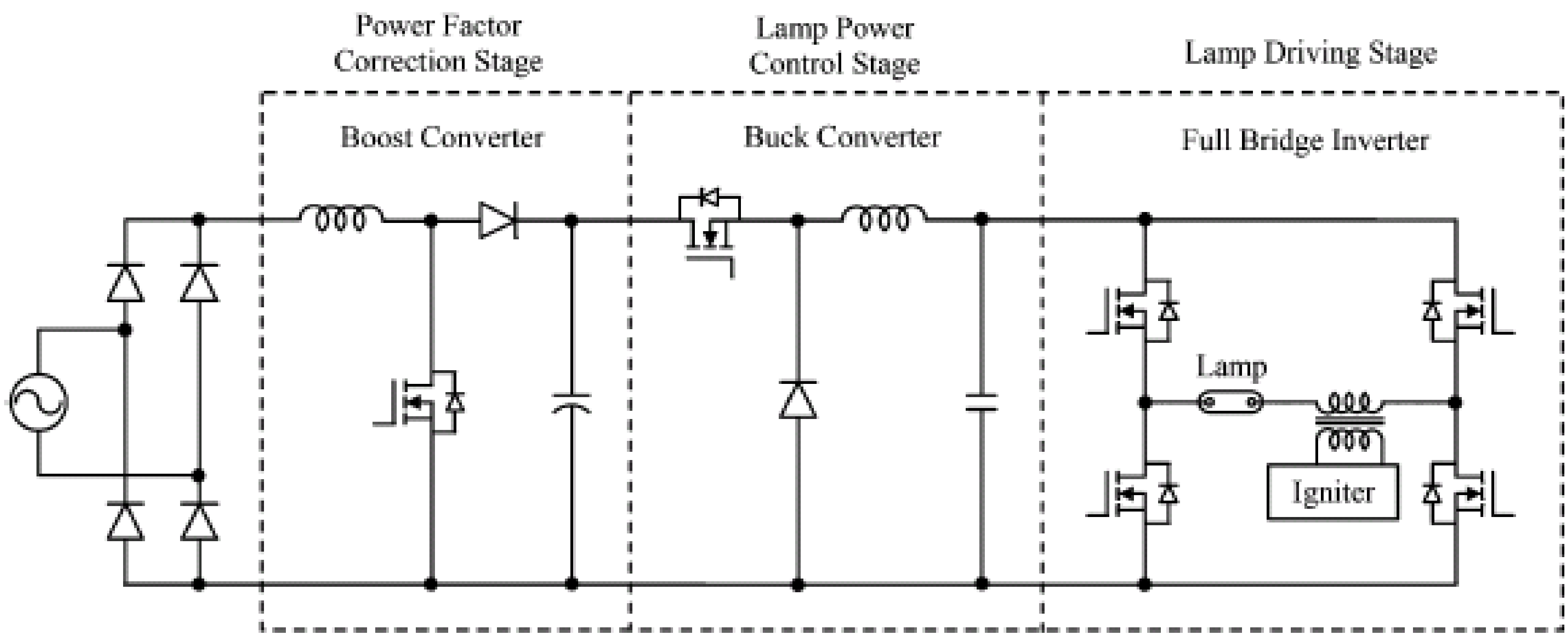


- Higher cost
- Small and light
- Integrated ignitor
- No flickering and audible noise
- With lamp power regulation (more intelligent)

HID Ballast Block Diagram



Three Stage HID Electronic Ballast



Achieve high PF, low I_{THD}

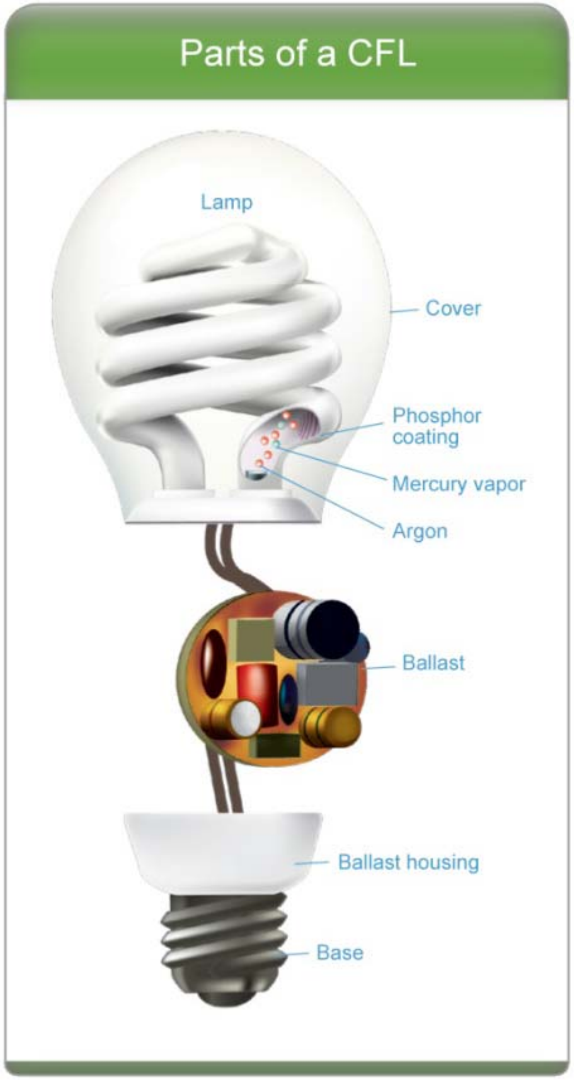
Provide constant lamp power regulation

Provide high ignition voltage
Avoid Acoustic resonance(10K~500kHz)

More Light from Less Power - CFL

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



Source: Energy Star

How to choose in CFL?

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?

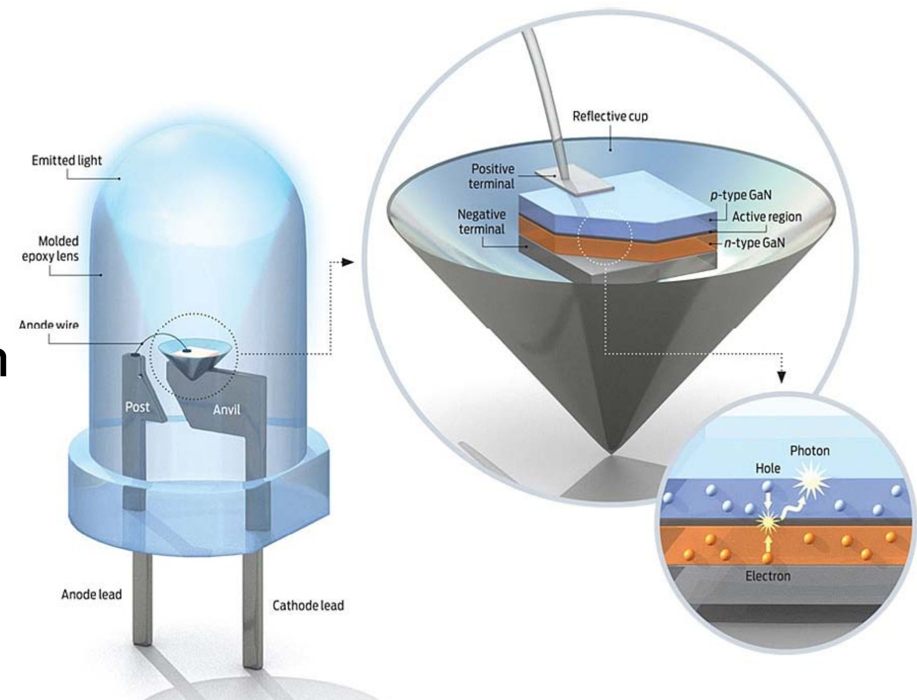
	Table/ Floor Lamp	Pendant Fixture	Ceiling Fixture	Ceiling Fan	Wall Sconces	Track Lighting	Outdoor Covered
Spiral	☺		☺	☺	☺		
Covered A shape	☺	☺		☺			
Globe		☺					
Tube	☺		☺		☺		
Candle					☺		
Indoor Reflector						☺	
Outdoor Reflector							☺

More Light from Less Power - LED

- 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

- 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.



Source: Energy Star

More Light from Less Power - LED

- No Mercury
- CRI of 92, some LED lights are dimmable
- Long Life (> 50000 hrs), high efficacy (160 lm/W@350mA)
- They generally consume 80% less power than incandescent lamp and 50% of CFL.
- 12W LED can replace 65W Incandescent??

How to choose an LED? Step1

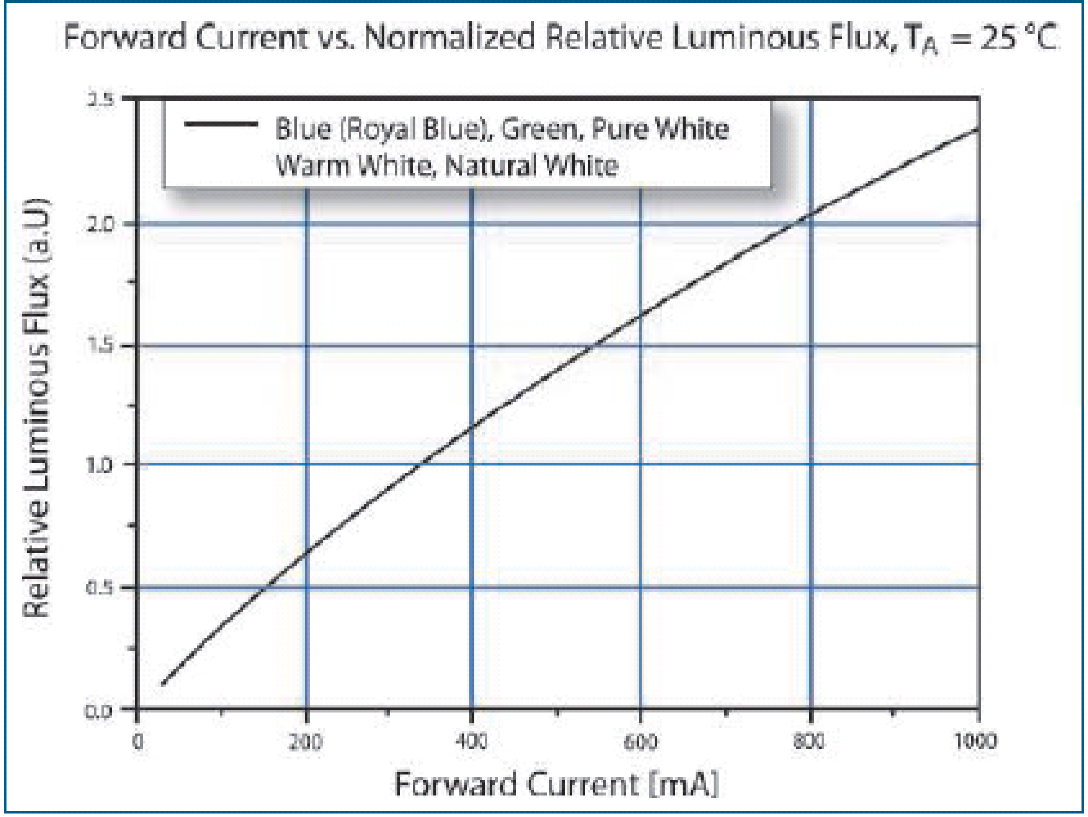
LED	lux	Drive Current	Test temp (^{0}C)
MFR 1	91 lm	350 mA	T_A 25
MFR 2	107 lm	350 mA	T_J 25
MFR 3	130 lm	700 mA	T_A 25
MFR 4	100 lm	350 mA	T_{pad} 25

- Purchase decision shall not be made on top line numbers
- Light output, light efficacy, lumen maintenance, operating temperature

How to choose an LED? Step 2

- 70% output after 50000 hours
- Maximum output at any instant

FIGURE 1: EXAMPLE OF FLUX NORMALISATION GRAPH



How to choose an LED? Step 2

LED	lux	Normalized lux	Test temp (^0C)
MFR 1	91 lm	164 lm	T_A 25
MFR 2	107 lm	182 lm	T_J 25
MFR 3	130 lm	130 lm	T_A 25
MFR 4	100 lm	165 lm	T_{pad} 25

- LED from MFR 3 is the giving least lumen output at 700 mA
- We are not comparing all the LEDs at common temperature, use temperature derating graphs

How to choose an LED? Step 3

LED	Normalized lux	Data sheet T_J max	Operating T_J for T_A of 25^0C	Flux derrating factor	Actual Flux
MFR 1	164 lm	145	135	72%	118 lm
MFR 2	182 lm	150	128	78%	142 lm
MFR 3	130 lm	125	141		
MFR 4	165 lm	150	130	81%	133 lm

- MFR 3 Exceeds maximum junction temperature at this operating condition
- Check for output lumen after 50,000 hours

How to choose an LED? Step 4

LED	Actual Flux	Data sheet T_J max	Operating T_J for T_A of 25^0C	L70/50kh conditions	Current to achieve lumen maint.	Actual Flux
MFR 2	142 lm	150	128	T_J<85C	407 mA	107 lm
MFR 4	133 lm	150	130	T_J<135C	700 mA	133 lm

- MFR 2 – To achieve 50k hrs, the LED shall be operated at 407 mA at T_J at 85^0Cand it delivers a 107 lm at the end of 50000 hrs
- Off the shelf drivers are available for 350 mA and 700 mA

Source: http://www.philipslumiled.scom

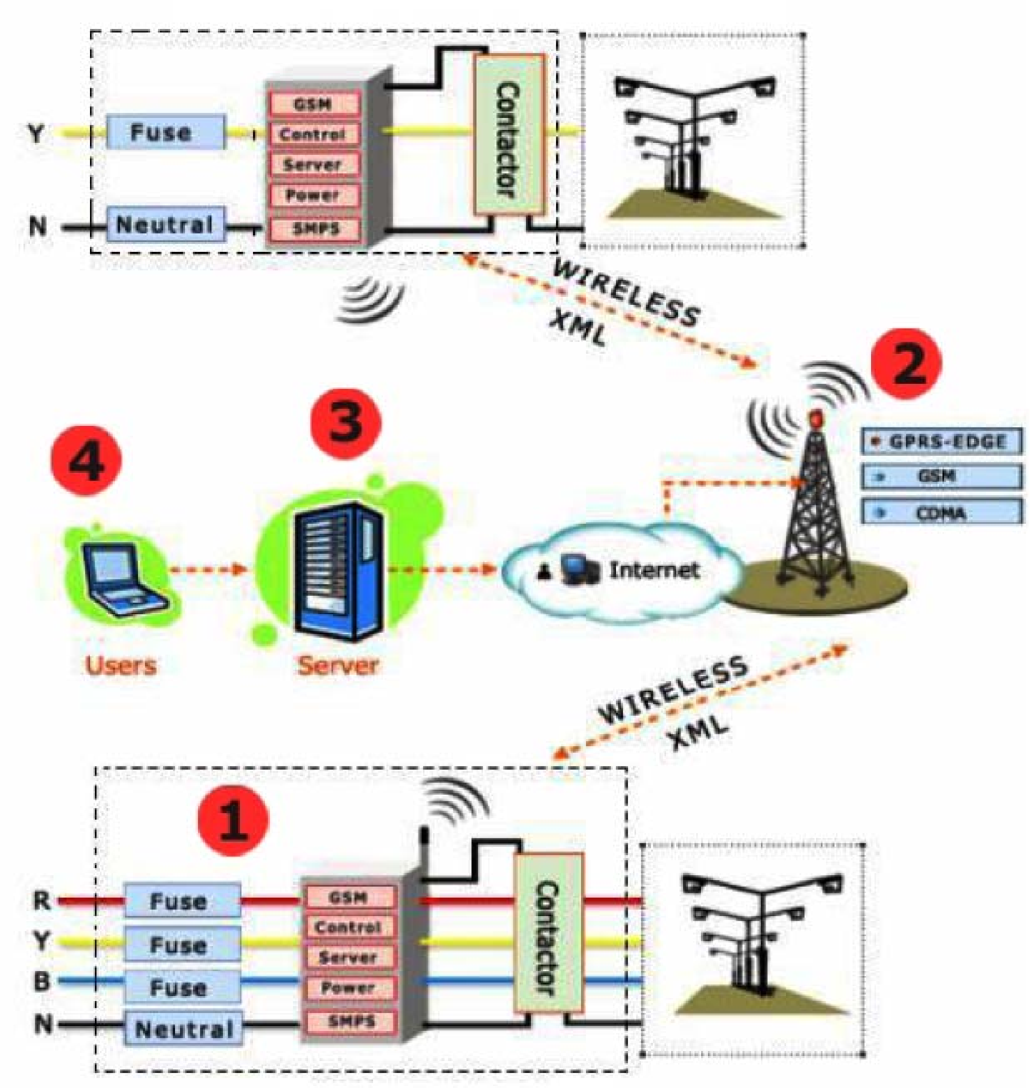
Lighting Controls

- 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

- 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



Source: *M2M Brochure*

Centralized control of street lights

- 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

- 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

- Energy efficiency is a really smart way to reduce demand on power system and reduce CO_2 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

- Re-lamping - Use high efficiency ballast and lamps
- Perform simple maintenance which will improves 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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http://www.ese.iitb.ac.in/~suryad