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

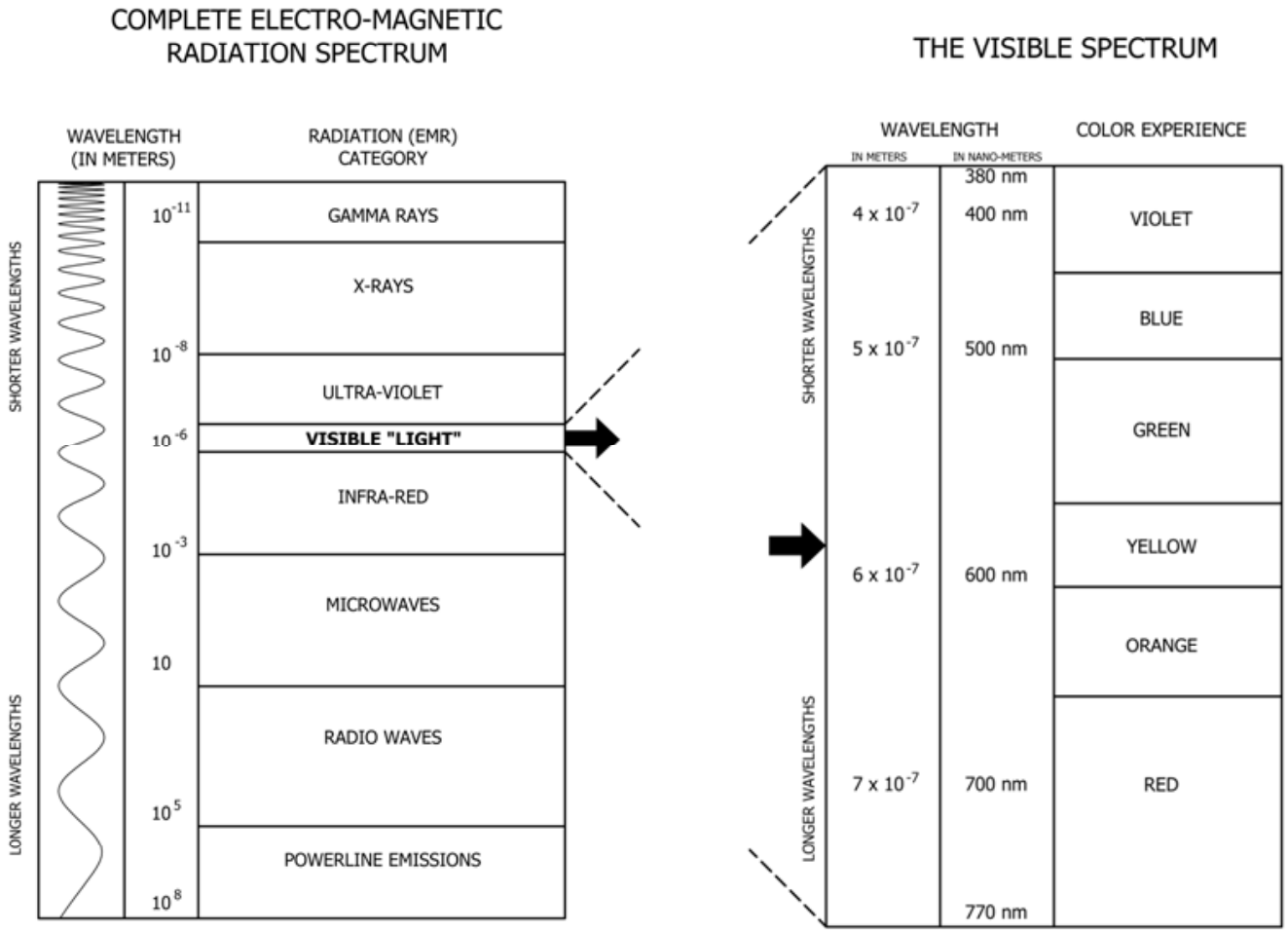
Why Energy Efficiency in Lighting?

- 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

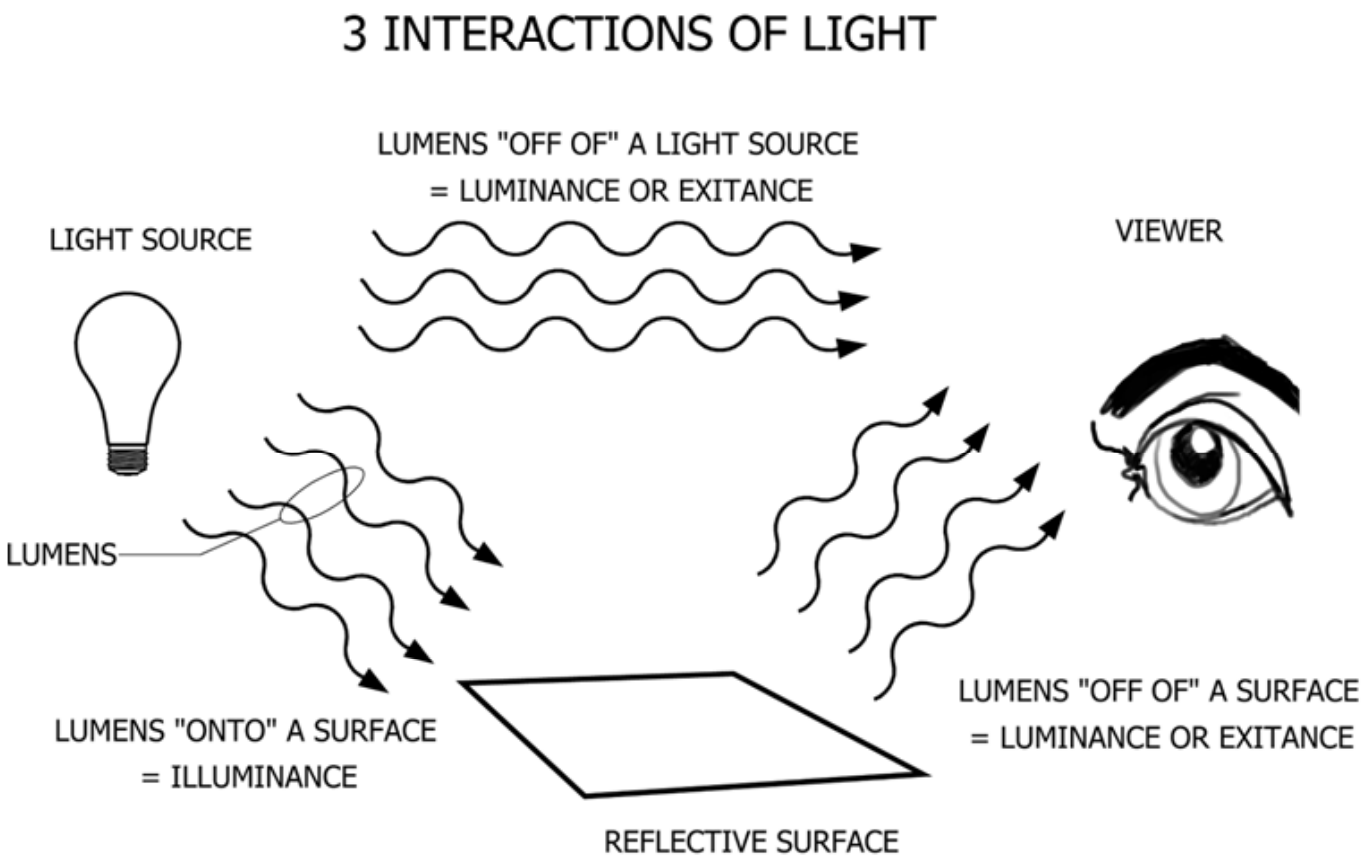
- Light is a member of a large family called electromagnetic radiation (EMR)
- Heat, light, x-rays, microwaves, U.V. are all examples of EMR
- EMR travels with speed of light and has a wide spectrum of wavelength
- The visible spectrum includes radiation from 380 Nm to 750 Nm in wave length
- Visible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

Spectrum of EMR-Light



Source: www.thelightingtextbook.com

Terminology in Lighting



Source: www.thelightingtextbook.com

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.

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)

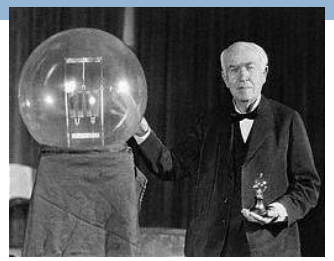
Color Temperature

- 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

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

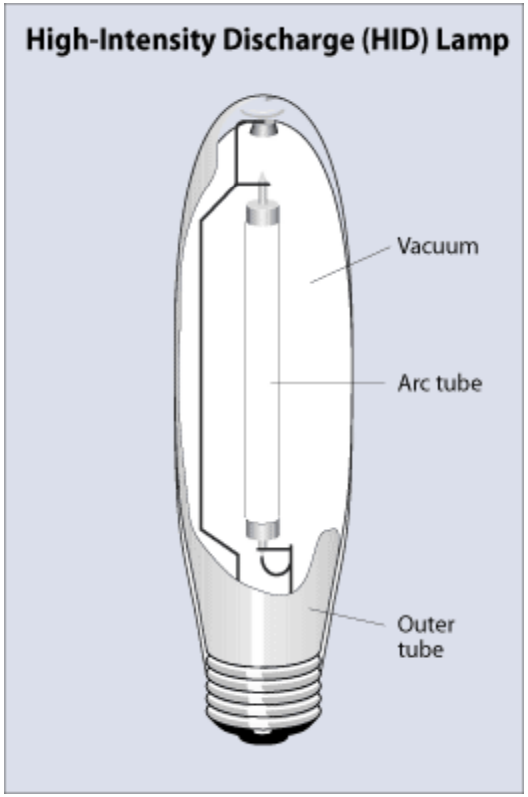
- Solid State Lighting
  - Light Emitting Diode (LED)
  - Organic Light emitting diode (OLED)

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

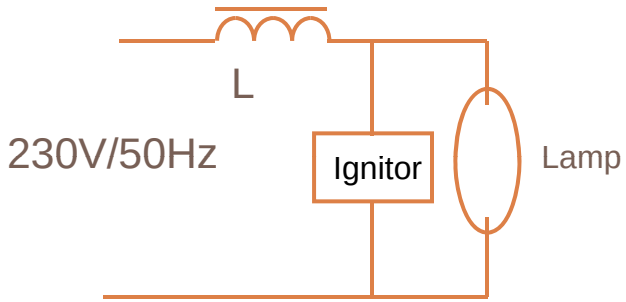
Source: American Council for Energy Efficient Economy

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

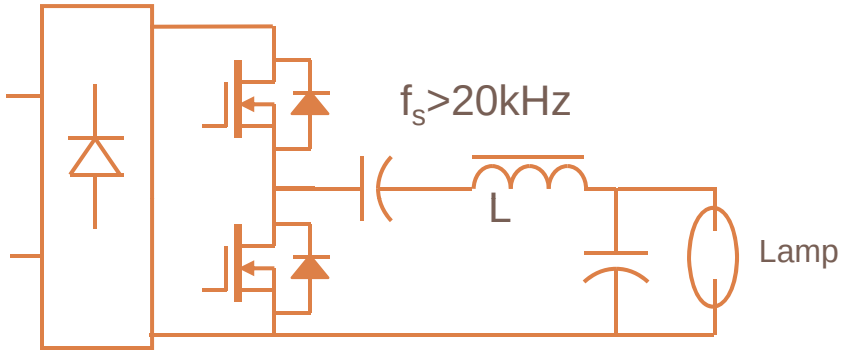
From Magnetic to Electronic Ballast

Magnetic Ballast



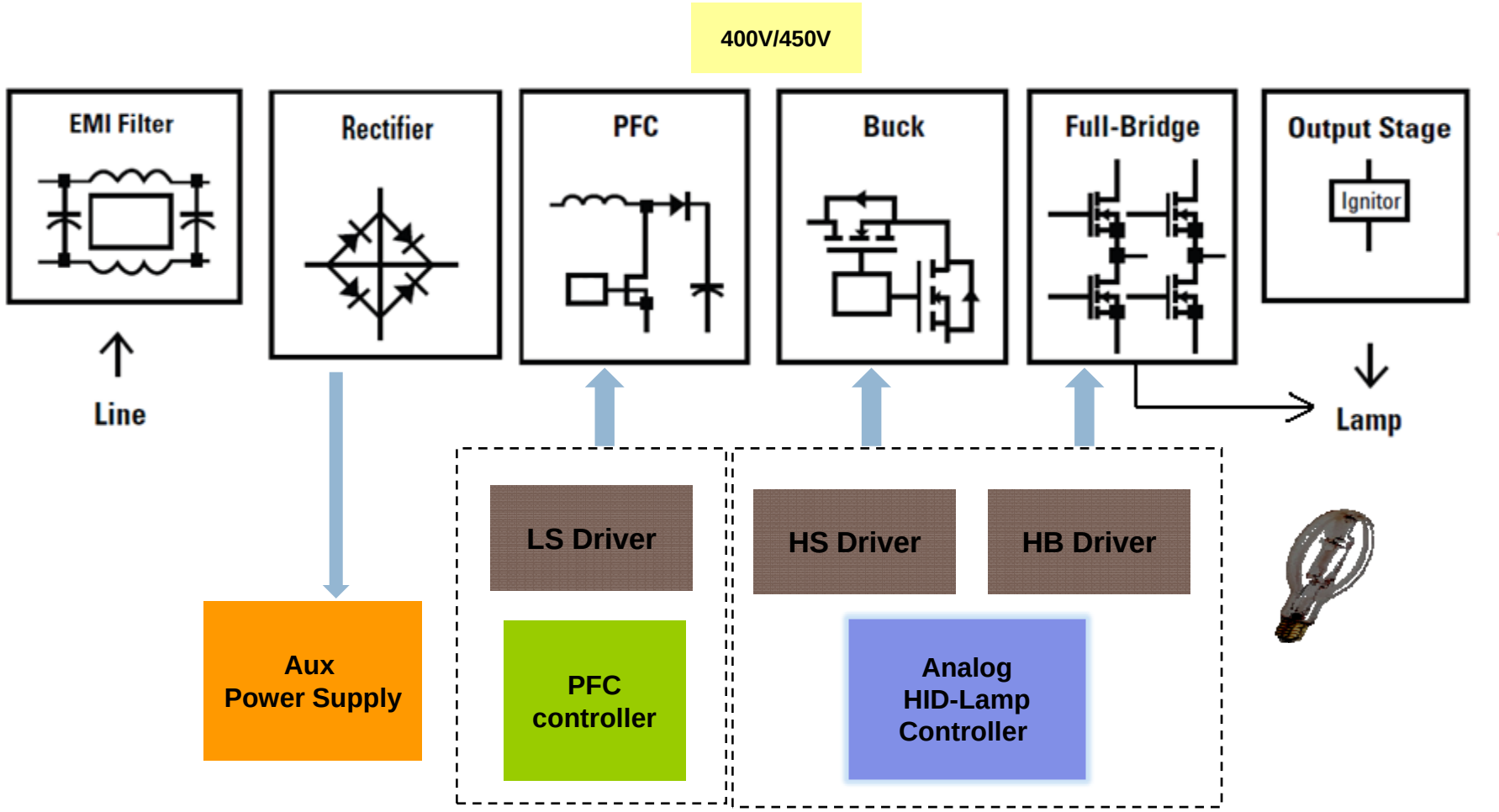
- Simple, low cost, high reliability
- Large and heavy
- External ignitor
- Re-ignition causes line frequency flickering
- No lamp power regulation

HF Electronic Ballast

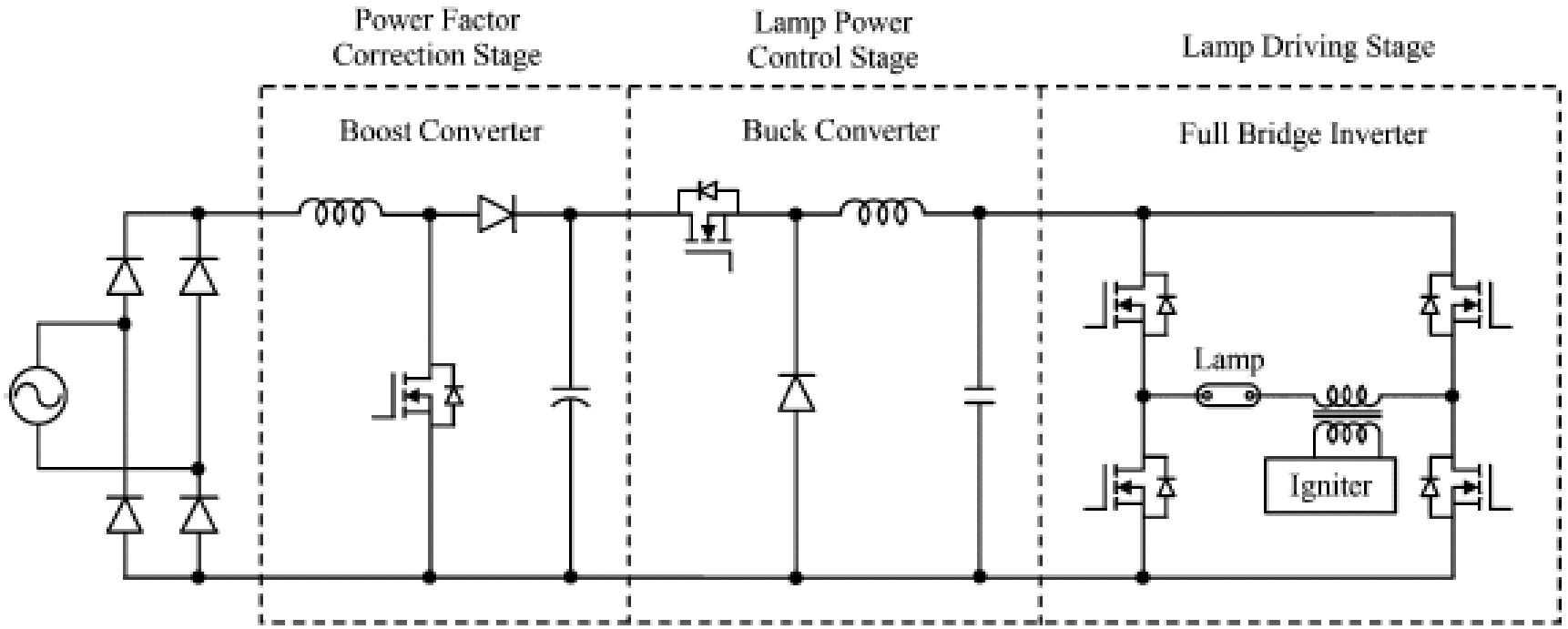


- Higher cost
- Small and light
- Integrated ignitor
- No flickering and audible noise
- With lamp power regulation (more intelligent)

HID Ballast Block Diagram



Three Stage HID Electronic Ballast



Achieve high PF, low I_{THD}

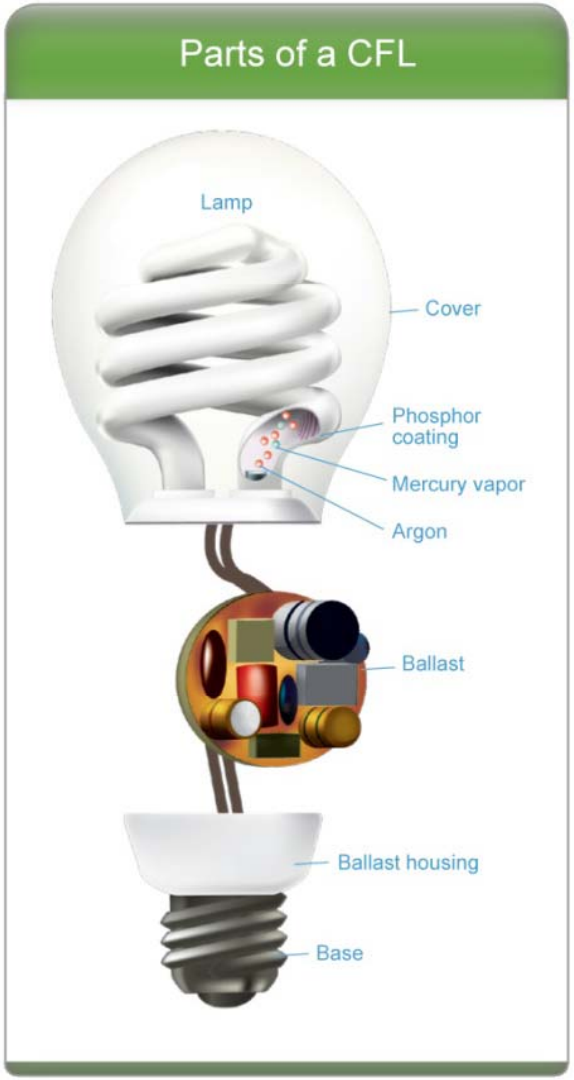
Provide constant lamp power regulation

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?

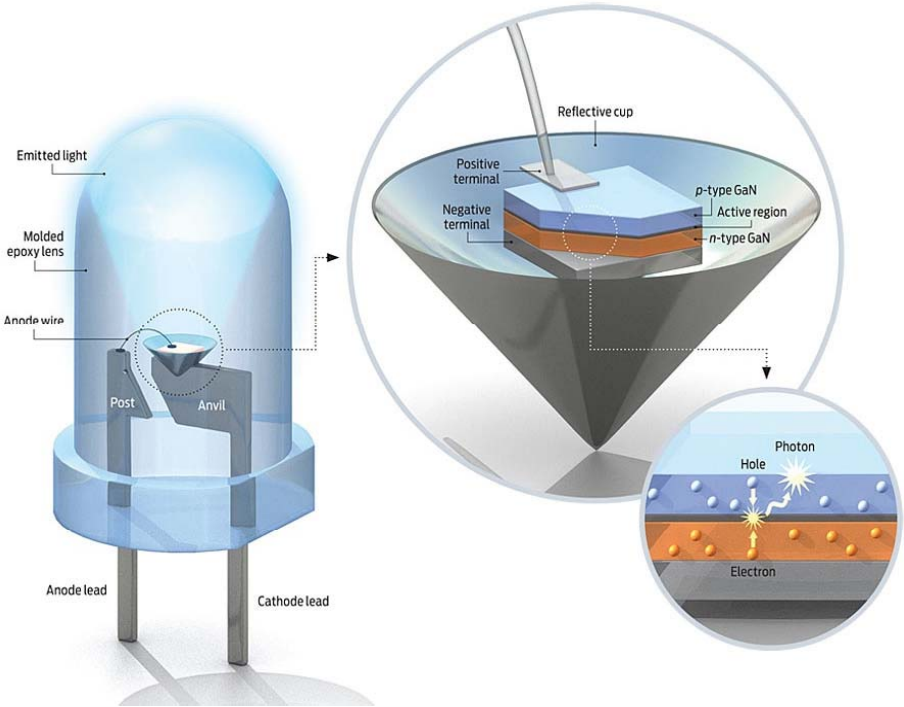
	Table/ Floor Lamp	Pendant Fixture	Ceiling Fixture	Ceiling Fan	Wall Sconces	Track Lighting	Outdoor Covered
Spiral	☺		☺	☺	☺		
Covered A shape	☺	☺		☺			
Globe		☺					
Tube	☺		☺		☺		
Candle					☺		
Indoor Reflector						☺	
Outdoor Reflector							☺

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??

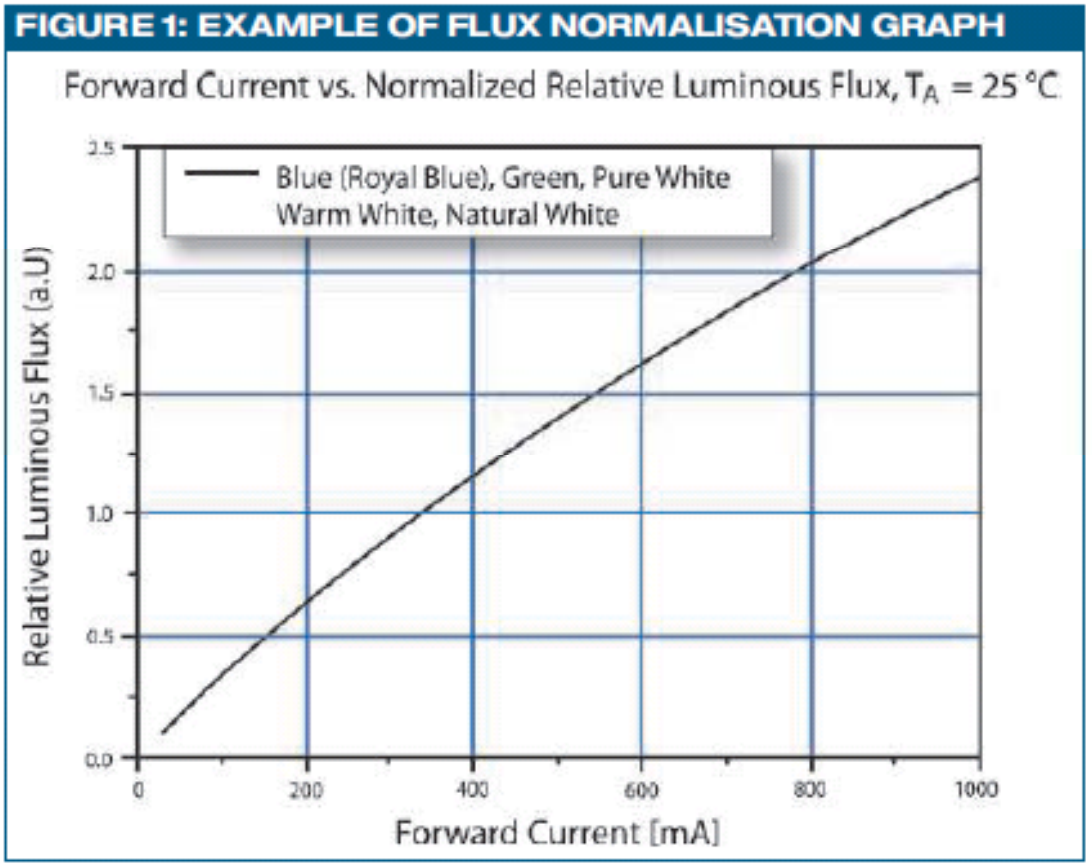
How to choose an LED? Step1

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



How to choose an LED? Step 2

LED	lux	Normalized lux	Test temp (^{0}C)
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^{0}C	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^{0}Cand 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

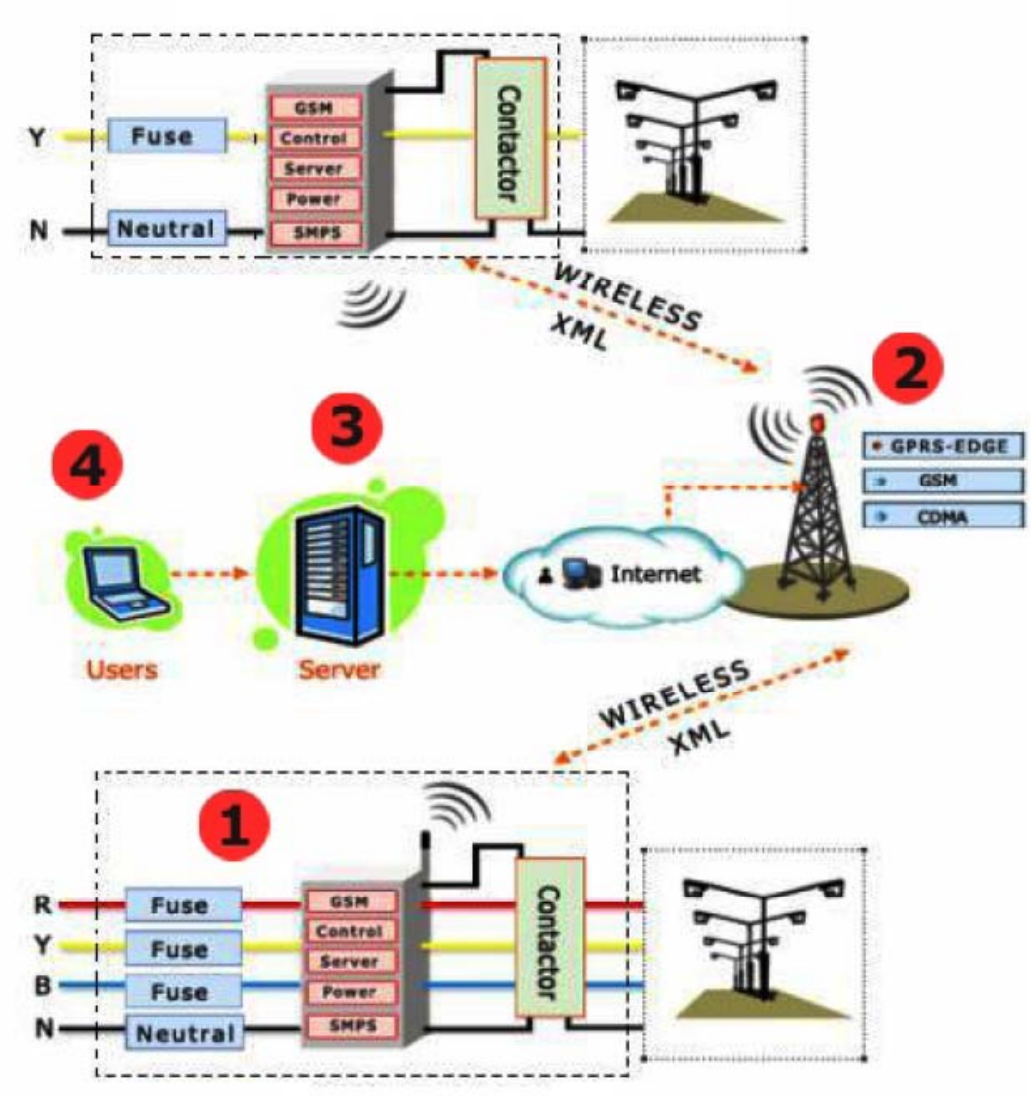
Lighting Controls

- 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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