LED ILLUMINATION: A CASE STUDY ON ENERGY CONSERVATION

Mrs. Landge Shubhangi Sudhir

Assistant Professor, shubhangi.landge1@gmail.com, 7774077173

Abstract- This paper deals with the energy saving potential possible by changing the illumination schemes. With increase in energy crisis there is a need of looking for additional energy sources or reduction in energy consumption without losing comfort. Energy audition is the new trend in the present scenario and play a major role in energy saving. One of the energy saving scheme in illumination is, by using natural light and/or use of LEDs. LEDs are having major advantages of longer life & almost negligible power consumption compared to any type of illuminating sources. The case study in a residential township deals with the replacement of existing conventional lighting scheme with LED lighting scheme will have huge energy saving potential, with payback period of even less than 15 months. The LED lighting scheme provides additional advantages as cool light, decreased maintenance cost and longer life.

Keywords – Light emitting diode (LED), compact fluorescent lamp (CFL), Color rendering index (CRI), Correlated color temperature (CCT), Coefficient of variation (CV), surface mounted diode (SMD), efficient lighting technology.

1 *INTRODUCTION*

Lighting accounts for 7 percent of a typical household's energy bill. One of the easiest ways to save energy is cutting lighting bill. In earlier day's incandescence and fluorescence lamps were mainly used for illumination. But these lamps are extremely inefficient. Only 5 percent of energy they use is converter into visible light. The development in SV, MV and metal halide makes possible to replace this old technology. But none of these technologies could improve the efficacy exceeding 200 lumens per watt and efficiency beyond 60-70%. The recent technology of compact fluorescent lamp (CFL) has improved the efficiency and it has really proved standards. CFLs use about 75 to 80 percent less electricity than an equivalent traditional bulb and can last up to 10 times longer. CFLs are great for replacing standard home light fittings but are more expensive and its illumination decreases with use.

A new kind of lighting became available with the advent of commercial LEDs (Light emitting diode) in the 1960s. LEDs also known as solid state lighting (SSL) are solid light bulbs which are extremely energy-efficient. LEDs will consume less electricity than conventional lighting including CFLs. LED sources are compact, which gives flexibility in designing lighting fixtures and good control over the distribution of light with small reflectors or lenses. These are simple solid state electronic devices that allow electricity to flow through them in one direction to produce a small amount of light. Bulbs for domestic use contain a large number of LEDs so that enough bright light is emitted. Because of the small size of LEDs, control of the spatial distribution of illumination is extremely flexible, and the light output and spatial distribution of an LED array can be controlled with no efficiency loss. Also they can withstand high voltage fluctuations in power supply and have longer operational life. A significant difference from other light sources is that the light is more directional, i.e., emitted as a narrower beam. LED lamps are used for both general and special-purpose lighting. They are still expensive, but they are the most efficient option and their payback period is small

The objective of this paper is to discuss the LED technology along with its benefits and applications over other type of lighting sources. The energy saving potential of LED is verified by replacing the CFL and FTL with LEDs in a residential area.

2 *LED TECHNOLOGY-*

A. Principle of operation

LED consists of a chip of semiconducting material doped with impurities to create a p-n junction. Like other diodes, current flows easily from the p-side (anode) to the n-side (cathode), but not in the reverse direction. Charge-carriers electrons and holes flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level and releases energy in the form of a photon.

The wavelength of the light emitted and its color depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes usually recombine by a non-radiative transition, which produces no optical emission as these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible, or near-ultraviolet light.

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have enabled making devices with ever-shorter wavelengths, emitting light in a variety of colors.

LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially GaN/InGaN, also use sapphire substrate. Most materials used for LED production have very high refractive indices. This means that much light will be reflected back into the material at the material/air surface interface. Thus, light extraction in LEDs is an important aspect of LED production.

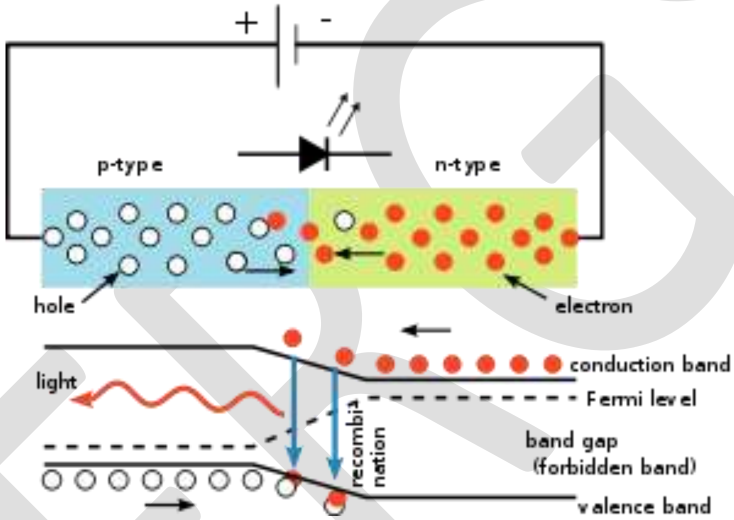

Fig 1. Circuit and Band Diagram of LED.

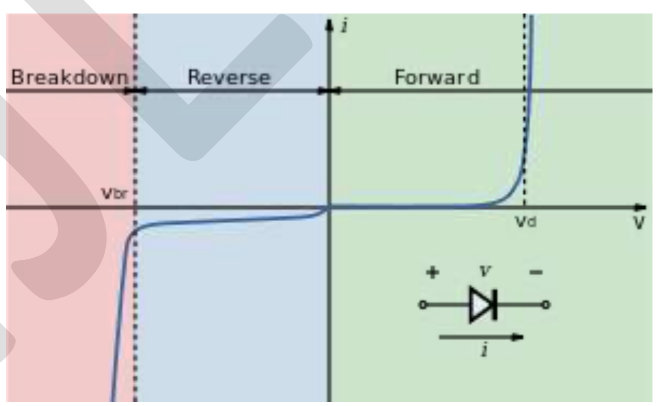

Fig. 2 I-V diagram for a diode.(LED)

B. ***Development in LED-*** For over 30 years, LEDs has been used in various areas of application, whether for industrial systems, car lights or advertising. LED technical development continues to step ahead. In the recent years, the white LEDs' luminous efficacy has increased to 130 lumens per watt and more. This is a trend that will continue into the future. The physical effect of electroluminescence was discovered more than 100 years ago.

1951	The development of a transistor marks a scientific step forward in semiconductor physics. It is now possible to explain light emission.
1962	The first red luminescence diode (type GaAsP), developed by American Nick Holonyak, enters the market. This first LED in the visible wavelength area marks the birth of the industrially-produced LED.
1971	As a result of the development of new semiconductor materials, LEDs are produced in new colors: green, orange and yellow. The LED's performance and effectiveness continues to improve.
1993	The first brilliant blue LED was developed and a very efficient LED in the green spectrum range (InGaN diode).
1995	The first LED with white light from luminescence conversion is presented and is launched on the market two years later.
2006	The first light-emitting diodes with 100 lumens per watt are produced. This efficiency can be outmatched only by gas discharge lamps.
2010	LEDs of a certain color with a gigantic luminous efficacy of 250 lumens per watt are already being developed under laboratory conditions. Progress continues to surge ahead. Today, further development towards OLED is seen as the technology of the future.

C. ***LED Terminology-***

i. **Color rendering index (CRI)** – CRI represents the quality of light and its accuracy to render color correctly. The ideal CRI is 100. Led bulb CRI rating ranges from 70 to 95.

ii. **Correlated color temperature (CCT)** - it is the measure used to describe the relative color appearance of white light source. CCT indicates whether the light source appears more yellow, orange, gold or more blue in terms of the range of available shades of "white". White shade can vary from warm white with higher red content to cool white with higher blue content. This is described by color temperature where warm white has lower value of 3000 Kelvin to than cool white of 5000 Kelvin.

iii. **Coefficient of variation (CV)** - A measurement of illuminance uniformity. The standard deviation of a set of grid values divided by the average.

3 *BENEFITS OF LED*

LED lighting is very different from other lighting sources such as incandescent bulbs and CFLs. Key differences include:

i. **Light Source**: LEDs are the size of a fleck of pepper, and a mix of red, green, and blue LEDs is typically used to make white light.

ii. **Direction**: LEDs emit light in a specific direction, reducing the need for reflectors and diffusers that can trap light. This feature makes LEDs more efficient for many uses such as recessed down lights and task lighting. With other types of lighting, the light must be reflected to the desired direction and more than half of the light may never leave the fixture.

iii. **Heat:** LEDs emit very little heat. In comparison, incandescent bulbs release 90% of their energy as heat and CFLs release about 80% of their energy as heat. Common incandescent bulbs get hot and contribute to heat build-up in a room. LEDs prevent this heat build-up, thereby helping to reduce air conditioning costs in the home.

iv. **Long-lasting** - LED bulbs last up to 10 times as long as compact fluorescents, and far longer than typical incandescent.

v. **Durable** - since LEDs do not have a filament, they are not damaged under circumstances when a regular incandescent bulb would be broken.

vi. **Mercury-free** - no mercury is used in the manufacturing of LEDs.

vii. **More efficient** - LED light bulbs use only 2-17 watts of electricity (1/3rd to 1/30th of Incandescent or CFL). LED bulbs used in fixtures inside the home save electricity, remain cool and save money on replacement costs since LED bulbs last so long. Small LED flashlight bulbs will extend battery life 10 to 15 times longer than with incandescent bulbs.

viii. **Cost-effective** - although LEDs are initially expensive, the cost is recouped over time and in battery savings. LED bulb use was first adopted commercially, where maintenance and replacement costs are expensive. But the cost of new LED bulbs has gone down considerably in the last few years and is continuing to go down. Today, there are many new LED light bulbs for use in the home, and the cost is also less.

ix. **Light for remote areas and portable generators** - because of the low power requirement for LEDs, using solar panels becomes more practical and less expensive than running an electric line or using a generator for lighting in remote or off-grid areas. LED light bulbs are also ideal for use with small portable generators which is used for backup power in emergencies.

4 *LIMITATIONS OF LED*

i. High initial Price- LEDs are currently more expensive (price per lumen) on an initial capital cost basis, than most conventional lighting technologies

ii. Temperature dependent- LED efficiency and life drop at higher temperature. It limits the use of LED for physical replacement of existing filament and compact fluorescent types. Adequate heat sink is required to increase life.

iii. Sensitive to Heat- Led lamps are sensitive to excessive heat. LED lamps should be checked for compatibility for use in totally or partially enclosed fixtures as heat buildup could cause lamp failure.

iv. Voltage sensitive- **:** LEDs must be supplied with the voltage above the threshold and a current below the rating. Current and lifetime change greatly with a small change in applied voltage. Thus they require a current-regulated supply

v. Flicker- LED lamps may flicker. The extent of flicker depends on the quality of DC power supply built into the lamp structure.

vi. Sensitive to Surges Led lamps may be sensitive to electrical surges. It depends on design of lamp. This is generally not an issue with incandescent lamp. Power circuit that supply LED lamp can be protected from electrical surges through the use of electrical protective devices.

vii. Efficiency- The luminous efficacy of LEDs decreases as the electric current increases. Heating also increases with higher currents which compromise the lifetime of the LED. These effects put limits on the current through LED in high power applications.

5 APPLICATIONS OF LED

LED has an extensive list of applications across a number of industry segments. Some of these are Electric Light Sources, Semiconductor Technology, Audio Electronics, Optics Medical Devices, Computer Peripheral Equipment, Traffic Control Systems, Scanning Equipment, Computer Data Transfer Devices, Heat Transfer & Control Systems, Kitchen Appliances, Dental Equipment, and Automobile Lighting Systems.

While LED can be found across several areas, it's predominantly featured in lighting systems and devices. LED lighting can be used in specific areas as in healthcare centers, cinema halls, hotels, aircraft, automobiles, computer peripherals and other such areas.

i. Automotive- LED is used in automobiles for interior uses which include indicator lights on dashboard gauges, audio status light, security status light and warning signals. The exterior uses includes third brake lights, left and right rare lamps, turn signals etc.

ii. Backlight Source-the mobile phone integrate LEDs as surface mounted diode (SMD). One mobile phone takes two LED backlight sources and six SMD LED key lights.

iii. Display Screen-The LED screen has become the new display medium for advertising and information. It is commonly use in concert, arena and trade show venues. LED display screens have been widely adapted in various fields due its advantages such as high brightness, dynamic visual display, high reliability, low energy consumption, long service life, display content diversity, high durability and low maintenance cost.

iv. Electronic Equipments- due to attributes such as low power consumption, small size and long life Led have become preferred light source on various electronic equipments. Led is integrated as warning lights and indicators on most electronics.

v. General Lighting- LEDs are used in advertising billboards, illumination of commercial building exteriors, landmark buildings, bridges, roads, town centers and landscape lighting. Their long life, rich color and easily controlled features with integrated electronics offer a scalable lighting solution. Now a day's LEDs are also used in many airports, subways, hotels, shopping centers and individual homes feature.

6 ENERGY AND COST SAVING OF LEDS

LED is a highly energy efficient lighting technology. Residential LEDs especially ENERGY STAR rated products use at least 75% less energy, and last 25 times longer, than incandescent lighting. The biggest benefit of LED lighting is its lifespan. An LED bulb will last approximately 50,000 hours i.e. five times longer than a CFL bulb. If the bulb is left on for eight hours per day, it will last over 17 years. During that lifespan, an LED bulb will use 300 kilowatt hours of electricity. Widespread use of LED lighting has the greatest potential impact on energy savings. In comparison we need five CFLs to match the 50,000-hour lifespan of an LED. Those five CFLs would use 700 kilowatt hours of electricity. The LED bulb saves 400 kilowatt hours of electricity compared to the CFL and 2,700 kilowatt hours compared to the incandescent bulb.

The table below compares a 60 watt (W) traditional incandescent with energy efficient bulbs that provide similar light levels.

Comparisons between Traditional Incandescent lamp, Halogen Incandescent lamp , CFLs, and LEDs

	60W Traditional Incandescent	**43W Energy-Saving Incandescent**	**15W CFL**		**12W LED**	
			60W Traditional	**43W Halogen**	**60W Traditional**	**43W Halogen**

Energy $ Saved (%)	–	~25%	~75%	~65%	~75%-80%	~72%
Annual Energy Cost	$4.80	$3.50	$1.20		$1.00	
Bulb Life	1000 hours	1000 to 3000 hours	10,000 hours		25,000 hours	

Case study: Replacing conventional lighting system and CFL by LEDs

In residential buildings, lighting accounts for 30 – 40 % of total energy consumption. Lighting is an area which offers many energy efficient opportunities in almost any building, existing as well as new building. A typical residential building has many lighting requirements and each normally has its own set of options for improving lighting efficiency. Lighting control is one of the easiest ways to make substantial energy savings with relatively small investment and is one of the main energy saving measure.

To analyze the performance of LED lighting as energy efficient lighting a case study was conducted in a township. This township has 28 buildings and 1100 flats. Only the lighting provided for lobbies, parking and streetlight is considered for this study. The luminaries used for lobbies and streetlight are CFL and for parking is fluorescent tube light.

In the township there were 782 CFL lamps in lobbies & 148 CFL Lamps for streetlight, which were ON for the purpose of vigilance throughout the night. The tube lights used to ON from 8 PM to 6 PM (Timing use to vary subject to season change). There were 837 fluorescent tube light in parking, which was ON for the purpose of vigilance throughout the night. All the lights (on an average) working for 10 hours a day.

Total power consumption with 40 Watt fluorescent tube light,

$P_1 = 837 \times 40 = 33480$ Watts.

Total power consumption with 65 Watt CFL,

$P_2 = 148 \times 65 = 9620$ Watts.

Total power consumption with 11 Watt CFL,

$P_3 = 78\,2 \times 15 = 11730$ Watts.

Daily energy consumption for 10 hours working of lamps is,

$E = (33480+9620+11730) \times 10 = 548.3$ kWhr.

The financial burdon = 548.3 × Rs. 8.78 =Rs. 4,814.074

Total expenditure in one year= Rs. 4,814.074 × 365 = Rs.17,57,137.01

If these fluorescent lights and CFLs were replaced with LEDs,

a) 11 Watt CFLs in lobbies were replaced by 12 Watt LED lights. Total LED lights required are 782.
Total power consumption = 78 2 × 12= 9384 Watts

b) 40 Watt fluorescent lamps in lobbies were replaced by 12 Watt LED tube lights. Total led tube lights required are 837.
Total power consumption = 837 × 12 = 10044 Watts

c) 65 Watt CFL in streetlight were replaced by 30 Watt LED lights. Total led lights required are 148.
Total power consumption = 148 × 30 = 4440 Watts

Daily consumption=(9384+10044+4440) × 10 =238.68 kWhr

Energy saved per day=548.3 kWhr-238.68 kWhr=309.62kWhr

Financial burden per day=238.68 kWhr×Rs.8.78=Rs. 2095.61

Financial burden per year= Rs. 2095.61×365=Rs. 7,64,897.80

Financial saving per year= Rs.17,57,137.01- Rs. 7,64,897.80

=Rs.9,92,239.21

Cost of LEDs-

i) LED 12 Watt Rs. 1100.
ii) LED 30 Watt Rs. 2500.

Total cost invovled in replacement of LEDs= 148×Rs. 2500+837×Rs. 1100+782×Rs. 1100

= Rs. 21,50,900

Payback period = total cost of LEDs/ Financial saving per year.

= Rs. 21,50,900/ Rs.9,92,239.21

= 2.16 years

Years=26 months.

It can be seen that energy saving potential is possible by replacing the present system of conventional tube lights and CFL with LEDs. LED last for 75000 to 100000 hours. Taking 75000 hours life, a LED system will last for at least 10 years. These high-quality LEDs with their very long lifetime are getting cheaper, and the market is currently exploding.

7 CONCLUSION

It has been observed that LED illumination is better than any general illumination systems (including CFLs) in terms of energy saving and cost effectiveness. Replacing light bulbs and fluorescent tubes with LEDs will lead to a drastic reduction of electricity requirements for lighting. Since 20-30% of the electricity consumed in industrial economies is used for lighting, considerable efforts are presently being devoted to replacing old lighting technologies with LEDs

REFERENCES:

[1] Khanna V. K. (2014) Fundamentals of Solid State Lighting: LEDs, OLEDs, and Their Application in Illumination and displays, CRC Press.
[2] The life and times of the LED – a 100-year history, Nature photonics, vol. 1, April 2007.
[3] Schubert, E. F. and Kim, J. K. (2005) Solid-State Light Sources Getting Smart, Science, 308, 1274
[4] Savage, N. (2000) LEDs light the future, Technology Review, vol. 103, no 5, p. 38–44, September–October 2014
[5] "Model and Predict the Performance of LEDs for Solid State Lighting - Accurately and Quickly", Technical Note, Lambda Research Corporation 2007
[6] McKinsey "Lighting the Way", 2011
[7] 2011 European Commission green paper "Lighting the future- accelerating the deployment of innovative lighting technologies" R.D. Dupuis and M.R. Krames, J. Light wave Tech. 26, 1154 (2008).
[8] S. Nakamura and M.R. Krames, Proc. IEEE 101, 2211 (2013).
[9] Fred Schubert: Light Emitting Diodes, 2nd edition, (2006).

International Journal of Engineering Research and General Science Volume 4, Issue 2, March-April, 2016
ISSN 2091-2730

[10] Dr. Norbert Harendt" Simulation and Optimization of Optical Systems" 2008 Luger Research & LED-Professional.

[11] Ethan Biery, Thomas Shearer, Roland Ledyard, Dan Perkins, Manny Feris " Controlling LEDs " Technical white paper May 2014.

[12]Isamu Akasaki, Hiroshi Amano and Shuji Nakamura" Blue LEDs – Filling the world with new light" The Nobel Prize In Physics 2014, The Royal Swedish Academy of Sciences