Solid State Lighting, A solution for Power Crisis in Bangladesh

K. M. Ahsan-uz-Zaman[1], Kafi Mohammad Ullah[2], Md. Shaidul Kabir Milon[3], A S M Sayam[4], Abdul Wahed[5]
[1,2,3,4] Dept. of EEE, Mymensingh Engineering College (University of Dhaka), Mymensingh
[5]Faculty, Dept. of EEE, Mymensingh Engineering College (University of Dhaka), Mymensingh
[1]k.m.ahsanuzzaman@gmail.com

***Abstract*—Electricity is the most usable form of energy. For a developing country like Bangladesh, electricity plays an important factor. Due to increasing population and rapid industrial growth, the country lags behind than its rising demand of electric power supply. Power generation in Bangladesh is mostly dependent on natural gas, coal and fossil fuel which are also responsible for carbon emission. Alternative measures should be taken to resolve this power crisis. If the present power consumption can be reduced using smart energy efficient appliances then it would be possible to meet up the demand of the consumers with the present production capacity. Lighting is responsible for a gentle amount of energy consumption over the year. In this paper we discussed about using smart technologies like Solid State Lighting in terms of reducing energy consumption on lighting sector. Light emitting diode (LED) based solid state lighting technology have potential to exceed the efficiency of conventional lamp based lighting systems. LED offers better quality in lighting, have much longer lifespan and comparatively better on durability with only drawback of initial high pricing. In terms of much longer lifespan, this initial cost is not much accountable. This paper represents the features and efficiency of solid state lighting as well as comparison among conventional lighting and LEDs.**

Keywords—solid state light; power crisis; energy efficient technology; LED

I. INTRODUCTION

A universal trend towards the progressive development of an environmentally sustainable society has brought about a substantial demand for innovative, energy-efficient technology. Being a developing country Bangladesh is not much capable of utilizing renewable resources in terms of energy generation. Power sector of this country is much dependent on natural gas and fossil fuels. If the power consumption can be reduced somehow, this power crisis can be resolved gradually. Lighting is responsible for a large amount of energy consumption over the country. This research is focused on reducing the energy consumption on lighting sector. Reducing cost on lightening can be one of the solutions for energy crisis. This will also make the way for achieving the global goal of energy efficient technology implementation. Switching from provisional lighting systems to smart energy efficient lighting technology offers various advantages over energy efficiency and reducing cost for general usage. There are three major light source and their principles are much different.

Incandescence bulb - A tungsten filament is heated by electric current until it glows and emits light.

Fluorescent lamp – An electric arc excites mercury atoms which emits UV radiation. This radiation strikes the phosphor coating placed inside a glass tube. Then the UV rays are converted into visible light.

Solid state light – SSL is a kind of light emitting diode which are made of semiconductors.

Light emitting diode (LED) based solid state lighting system is the most promising energy saving solution for lighting applications. It have the potential of exceeding the conventional lighting systems in terms of advantages and features. However, replacing traditional lighting elements with LED can reduce the energy consumption in lighting sector at a significant scale. LED offers much longer lifetime than conventional lighting sources [1], as shown on the figure 1,

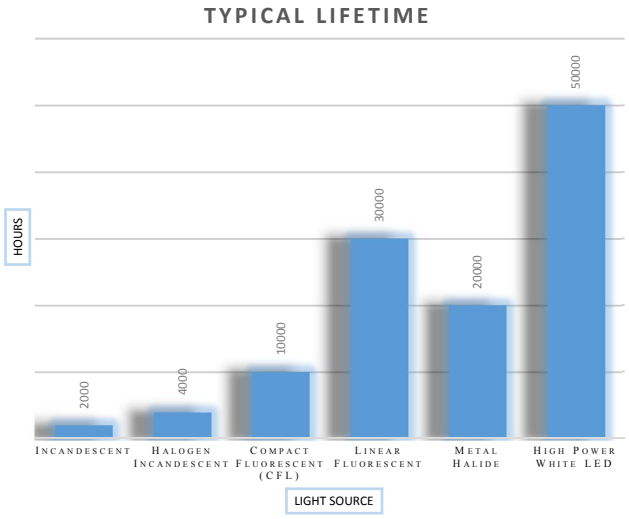

Fig. 1. Lifetime of various light source.

II. SOLID STATE LIGHTING

Solid-state lighting technology is actually based on Light Emitting Diode (LED). This lightening device is made of semiconductors and use electricity as power. It consists of a chip of semiconducting material treated to create a p-n (positive-negative) junction. Impurities are doped on the p-n junction. A Substrate is attached to the semiconducting diode to support the die, this contacts to applied power. A heat sink and a lens is also being installed on the LED chip. The lens controls light

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distribution characteristics of the mechanism. The whole package is covered by an outer casing.

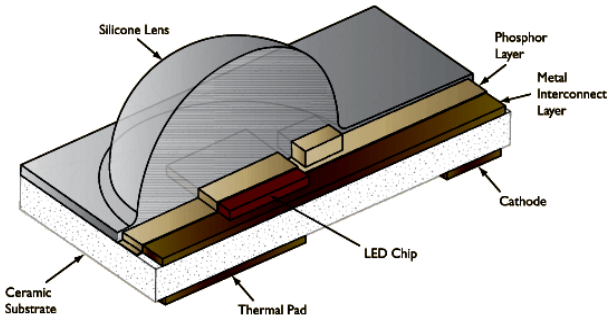

Fig. 2. Framework of a LED.

When the LED gets powered by electricity, electrons from the cathode (n-side) start to flow towards the anode (p-side). When the electrons and electron holes recombine, their electrical charges are cancelled out but the energy held by the electron is released instantly. This energy is released in form of electromagnetic waves and expelled as light.

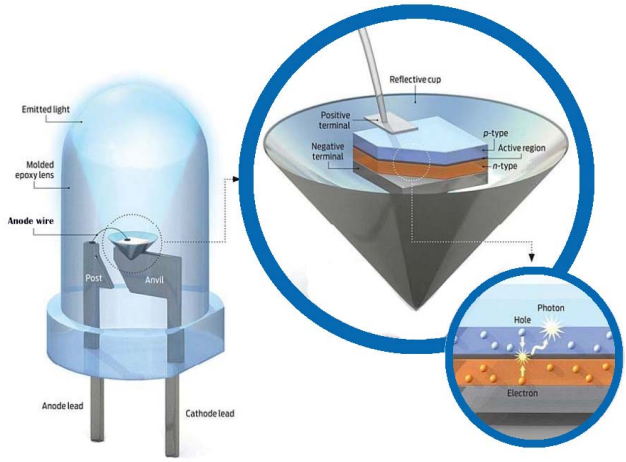

Fig. 3. Structure of a LED.

The wavelength of the light emitted by a LED depends upon the material used to construct the diode. Rather than the silicon and germanium used in normal diodes, compound semiconductors as like GaAs, AlGaInP, InGaN. Red LED is made of Aluminum Gallium Arsenide (AlGaAs). Green LED is based on Aluminum Gallium Phosphide (AlGaP) and Blue LED is from Indium Gallium Nitride (InGaN) [2]. White light is created by combining the light from red, green, and blue (RGB) LEDs or by coating a Blue LED with yellow phosphor. These white LEDs can be used as a replacement for conventional incandescent and CFL lighting.

III. Comparision Among Lighting Sources

Light is a member of large family called Electromagnetic Radiation (EMR). From 380 to 750 Nm in wavelength is considered as visible light. Among the other lighting sources LED based Solid State Lighting has much more efficiency [3]. Comparison among the light sources in terms of efficiency is shown in Table I,

TABLE I. EFFICIENCY OF LIGHT SOURCE

Light Source	**Typical Efficacy** ***(Lumens/Watt)***
Incandescent	15-25
Metal Halide	80-105
High Pressure Sodium	70-110
Compact Fluorescent (CFL)	40-70
Light Emitting Diode (LED)	60-140

LED offers more durable features and advantages rather than traditional lighting systems. LED bulbs are also free from producing hazardous materials like mercury. Different features of incandescent, CFL and LED light are described in Table II,

TABLE II. FEATURES OF INCANDESCENT, CFL & LED LIGHTS

Features	**Incandescent**	**CFL**	**LED**
Durability	Fragile	Fragile	Durable
Instant turn on	Yes	Slight Delay	Yes
Sensitivity to Temperature	No	Yes	No
Sensitivity to Humidity	Some	Yes	No
Heat Emitted	89.68 kJ/hour	31.65 kJ/hour	3.59 kJ/hour
Hazardous Materials	None	5 mg mercury/bulb	None
Frequent on/off Cycling	Some Effect	Shortens Lifespan	No Effect

IV. Efficiency of LED

The prospect of improving lighting technology has come up with recent advancement in terms of Solid State Lighting (SSL). These LED based SSL technology offers huge advantage when compared to fluorescent or incandescent lights in many aspects. Solid-state lighting (SSL) will mean greener homes and businesses that use substantially less electricity, making them less dependent on fossil fuels [5]. Solid State Lighting system is introducing superior features to users including,

- Low power consumption
- Ultra-long source life
- No UV or IR radiation
- No mercury content

Light Emitting Diodes (LEDs) are comparatively better than traditional incandescent and CFL light bulbs in account of efficiency. Power conversion efficiency is defined as the ratio of emitted optical power (P_o) to the applied electrical power,

$$\eta_c = \frac{P_o}{iV} = \eta_{ext}\ \frac{h\nu}{eV}$$

Where V is the voltage drop across the device and i is the supplied electricity.

LEDs have up to 53% efficiency on electrical power conversion [4]. Table III shows the comparison of luminous efficiency among the light sources.

TABLE III. COMPARISION OF WATT EQUIVALENT TO LIGHT OUTPUT AMONG THE SOURCES

Light Output *(Lumens)*	**Incandescent** *(Watts)*	**CFL** *(Watts)*	**LED** *(Watts)*
450	40	9-13	4-5
800	60	13-15	6-8
1100	75	18-25	9-13
1600	100	23-30	16-20

For about 1500 lumen of light output over 10 years considering 10 hours burning per day,

Traditional incandescent light required = 100W

Purchase price of the bulb = 40 BDT

Typical lifespan of the bulb = 8000 hours

Bulb required over the time period = 40 unit

Traditional electricity cost = 6 BDT/kilowatt-hour

Total power consumption over the time period,

$$N = \frac{PT}{1000} = \frac{100\times365\times10}{1000}\ \text{kWh} = 365\ \text{kWh}$$

Cost of electricity = 365 × 6 = 2190 BDT

Total expense = 40×40 + 2190 BDT = 3790 BDT

Compact fluorescent light (CFL) required = 23W

Purchase price of the bulb = 300 BDT

Typical lifespan of the bulb = 10000 hours

Bulb required over the time period = 2 unit

Traditional electricity cost = 6 BDT/kilowatt-hour

Total power consumption over the time period,

$$N = \frac{PT}{1000} = \frac{23\times365\times10}{1000}\ \text{kWh} = 83.95\ \text{kWh}$$

Cost of electricity = 83.95 × 6 = 503 BDT

Total expense = 2×300 + 503 BDT = 1103 BDT

Light emitting diode (LED) required = 12W

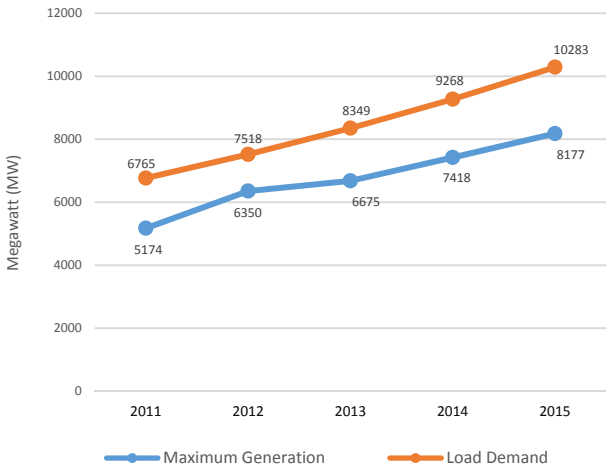

Fig. 4. Electricity generation vs demand in recent years.

Purchase price of the bulb = 620 BDT

Typical lifespan of the bulb = 50000 hours

Bulb required over the time period = 1 unit

Traditional electricity cost = 6 BDT/kilowatt-hour

Total power consumption over the time period,

$$N = \frac{PT}{1000} = \frac{12\times365\times10}{1000}\ \text{kWh} = 43.80\ \text{kWh}$$

Cost of electricity = 43.8 × 6 = 262.80 BDT

Total expense = 1×620 + 262.80 BDT = 882.80 BDT

With having only drawback of initial high cost, LED is still much more efficient for longtime usage. Alongside 3790 BDT for incandescent bulb and 1103 BDT for CFL, LED will only cost about 883 BDT in terms of 10 years usage for a single bulb as shown in the calculations above.

V. Power Sector Scenario of Bangladesh

Electricity is the main source of power for country's most of the economic, social and cultural activities. But our electricity sector is now in a sickbed. The energy infrastructure is quite small, insufficient and poorly managed. Total power demand exceeds the power generation capacity limit by a large number every year [6][7]. This situation resulting in load shedding throughout the entire country. Problems in the Bangladesh's electric power sector include corruption in administration, high system losses, low plant efficiencies, erratic power supply, electricity theft, blackouts, and shortages of funds for power plant maintenance [8]. Bangladesh Government has taken several attempts to balance the situation. In the Power System Master Plan (PSMP) -2010 demand forecast was made based on 7 % GDP growth rate. The electricity development is required to be accelerated to increase access and attain economic development. The desirable economic growth rate would be about 7% p.a [9]. Despite of all these measures taken, this country still lacks in electric power sector as shown in figure 4.

VII. SSL IN TERMS OF POWER CRISIS IN BANGLADESH

Solid state lighting have potential to reduce the cost of lighting in about one third in Bangladesh [10]. Solid state lighting also offers comparatively long lifetime and also reduce carbon emission. The main reason of LED based solid state lighting is not much used in Bangladesh is the unawareness about the feasible benefits and features that LED offers.

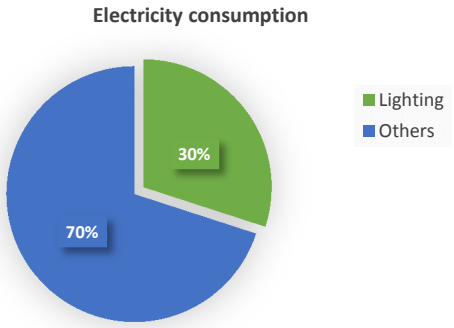

Fig. 5. Electricity consumption in different sectors.

As shown in the figure above, about 30 percent of the total energy consumption is for lighting purpose [10]. Two third of this lighting is by incandescent lights and other one third is by CFL across the country. LED generally consume 80% less power than incandescent lamp and 50% of CFL [11]. So replacing incandescent and CFL light sources with LED can save big amount of energy over the year. The power crisis in Bangladesh is rapidly increasing resulting large amount of load shedding over the year.

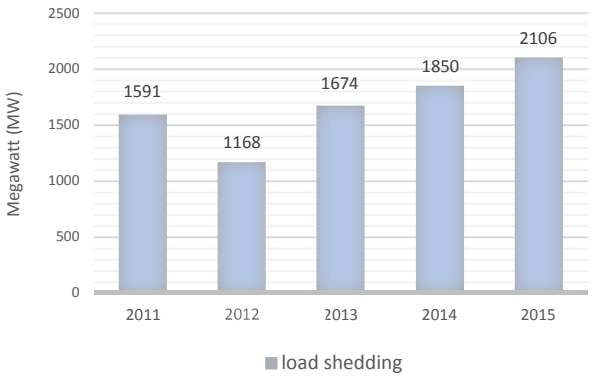

Fig. 6. Load shedding in last five years.

From the data shown in the figure 4, we can mathematically calculate the energy saving per year by replacing incandescent and CFL bulbs with light emitting diodes.

For the year of 2015,

Total demand of electricity = 10283 MW

Total generation over the year = 8177 MW

Load shedding = 2106 MW

Consumption over lighting purpose = 30% of 10283 MW = 3084.9 MW

Consumption by incandescent light = 2/3 of 3084.9 MW = 2056.6 MW

Consumption by CLF = 1/3 of 3084.9 MW = 1028.3 MW

IF incandescent sources are replaced by LED,

Energy saving over the year = 80% of 2056.6 MW = 1645.28 MW

Again, if CFL light bulbs are replaced by LED,

Energy saving over the year = 50% of 1028.3 MW = 514.15 MW

From above calculations, if conventional incandescent and CFL lights are replaced by LED then total saving from the lighting sector is about 2159.43 MW. Which clearly exceeds the annual load shedding across the country.

VIII. CONCLUSION

Replacing conventional lighting sources with LEDs can reduce the power consumption by a large amount in Bangladesh. With only drawback of initial high cost LED offers superior advantages in terms of efficiency and durability [12]. In this paper, calculation and statistics have shown that replacing incandescent and CFL bulbs with LED can resolve the power crisis over the country. Along with being efficient, LED will also take the country one step forward towards achieving the global goal of implementing ecofriendly smart technologies.

REFERENCES

[1] Department of Energy US (DOE), “Lifetime of White LEDs,” PNNL-SA-50957, September 2009

[2] Dronacharya College of Engineering, “LED Principle & Structure,” Electronics and Communication Engineering department report.

[3] STATELINE Eco Electric Corp., LED Watt Conversion & Light Replacement Guide.

[4] Philips, "All in 1 LED Lighting Solutions Guide". PhilipsLumileds.com. 2012-10-04. p. 15.

[5] Shigeru Suehero, Yoshiaki Shibata, “Electricity Saving Potential and Cost & Benefit of LED Lighting in Japan,” IEEJ, July 2011.

[6] Bangladesh Power Development Board, http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=20&Itemid=18.

[7] Finance Division, Ministry of Finance Government of People’s Republic of Bangladesh, Power and Energy Sector Road Map: An update‘2011, www.mof.gov.bd/en/budget/11_12/power/power_energy_en.pdf.

[8] Mohammad Asadul Haquea and Jalalur Rahman, — Power Crisis and Solution in Bangladesh ǁ Bangladesh J. Sci. Ind. Res.

[9] Bangladesh Power Development Board, http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=12&Itemid=126.

[10] Energypac Bangladesh, “Bangladesh Case Studies on Energy Efficient Lighting”, http://energypacelectronics.com.

[11] Leotek Electronics USA Corp, A Municipal Guide for Converting to LED Street Lighting. V7-101613. www.leotek.com.

[12] E. Fred Schubert, “Light Emitting Diodes, second edition,” ISBN: 0521865387, Cambridge University Press, Cambridge UK.