The Status of Energy Efficient Bulbs and the Potential Energy Savings in the Kathmandu Valley, 2013

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Abstract: This paper examined the status of energy efficient bulbs and estimated the potential of energy savings through the introduction of these bulbs in the Kathmandu valley for the year 2013. The type of research paradigm used in this report is of survey type. A set of questionnaires was made and the people living with their family in the Kathmandu valley were interviewed to answer those questions. From those answers, various information like the various types of bulbs used in the household, people's priority to various bulbs, total energy consumption per household for lighting and the potential energy savings by switching to the LED bulbs were obtained. This report intends to aware the importance of energy efficient lighting devices by calculating the possible energy savings from them in the Kathmandu valley.

Keywords: Energy efficient bulbs; Potential energy savings; Kathmandu valley; Survey; LED

1. Introduction

Lightening devices are those devices that consume electrical energy to produce light energy. They have replaced candles, kerosene lamps and other devices involving biomass for providing light energy in our daily life. Energy efficient lightening devices are those devices that consume less energy than other lightening devices for the production of the same amount of light energy.

Many types of lightening devices are available in today's world. Some of them are filament bulbs, incandescent lamps, halogen bulbs, compact fluorescent bulbs, LED lamps and so on. Some of them are more energy efficient to others and so they are termed as energy efficient lightening devices. If used over each and every household and other places where lightening is needed, they can save a considerable amount of energy. Electric lighting devices burn up to 25% of the average home energy budget. Saving energy in today's energy deficient world is of enormous importance. 60 watt of incandescent bulb is equivalent to 6-8 watt of LED bulb and 13-15 watt of CFL bulb for the production of same amount of light energy. Fluorescent lamps and LED lamps have higher efficiency compared to other lamps and so they are considered as the energy efficient lamps. (Energy efficient lighting, 2013)

Even though Nepal has high hydro power potential, its realization has not been done yet. Due to excess demand than energy production, we have been facing acute power crisis and so power outage is inevitable.(Water and Energy Commission Secretariat, 2011). Most of the urban households are still using filament and other inefficient lightening devises. The situation of rural households is even worse. They are still relying on resins and kerosene for lighting. They not only have lower efficiency, but also create indoor air pollution. So, switching to energy efficient devices is necessary as it saves precious energy and also helps in reducing emission of greenhouse gases.

Until now, there has been no study about how much energy can be conserved in Nepal if we switch from conventional lighting devices to energy efficient devices. Similarly, there has been no study that what is the response of average Nepali citizen towards these energy efficient bulbs as they are costly compared to traditional ones. So, the study intends on the finding the amount of energy that can be saved by using higher efficiency bulbs and people's perspective on the use of such bulbs in the Kathmandu Valley.

In spite of Nepal being rich in water resources, it could not harness them in effective manner due to various economic, political and technical difficulties resulting energy crisis. During dry winter days, people are facing severe power outage problems exceeding more than 12 hours a day daily. Since, demand is exceeding over supply, outage is increasing annually and it has been forecasted that the situation will be even worse in coming years.

Energy efficient bulbs consume less energy than conventional incandescent bulbs in producing same amount of light energy. Their use can lead to energy saving. As we know energy saving itself is equivalent to the production of the energy, use of energy efficient bulbs can help in reducing the energy crisis problem in Nepal.

The main objective of this research is to find the penetration level of energy efficient bulb such as LED in the Kathmandu Valley and to find the potential energy saving. Similarly the other objectives include to identify the various types of lightening devices that is used in the Kathmandu valley and their popularity and to find the people's views towards various lightening devices.

2. Methodology

A list of questionnaires was made to get feedback from the people about the type of lightening devices they use in their rooms, factors that affect their choice of the lightening devices and so on. The survey questions were distributed through email and in the printed form. Calculation of the sample size and spreadsheet formation from the received data was done. Calculation of the amount of energy saved by the energy efficient bulb (LED) over the conventional bulbs was done for further analysis.

3 Literature Review

3.1 Incandescent light bulbs

The incandescent light bulb, lamp or light globe is a source of electric light that works by incandescence (a general term for heat-driven light emissions, which includes the simple case of black body radiation). An electric current passes through a thin filament, heating it to a temperature that produces light. The enclosing glass bulb contains either a vacuum or an inert gas to prevent oxidation of the hot filament. Incandescent bulbs are also sometimes called electric lamps, a term also applied to the original arc lamps.

Incandescent bulbs are made in a wide range of sizes and voltages, from 1.5 volts to about 300 volts. They require no external regulating equipment and have a low manufacturing cost, and work well on either alternating current or direct current. As a result the incandescent lamp is widely used in household and commercial lighting, for portable lighting such as table lamps, car headlamps, and flashlights, and for decorative and advertising lighting.

Figure 1: Incandescent bulb

While regular incandescent bulbs last usually between 750 to 1,000 hours before burning out, some long-life bulbs last up to 2,500 hours. The tradeoff is that long-life bulbs are less energy efficient and produce less light per watt. On the plus side, we're all used to incandescent bulbs - they are inexpensive to purchase, the color of the light they produce is good, and they work well with dimmers.

3.1.1 Application

The incandescent bulb make use of the heat generated, such as incubators, brooding boxes for poultry, heat lights for reptile tanks, infrared heating for industrial heating and drying processes. In cold weather the heat shed by incandescent lamps contributes to building heating, but in hot climates lamp losses increase the energy used by air conditioning systems. (bulbsusa.com, Los Angeles, 2013)

3.2 Halogen light bulbs

Halogen light bulbs or halogen lamps produce light in a similar method to a regular incandescent bulb. Halogen light bulbs have a filament made of Tungsten, which glows when electricity is applied, same as a regular incandescent bulb. What makes halogen light bulbs different is that it is filled with halogen gas instead of argon gas like a regular bulb is. The halogen gas in halogen light bulbs removes the carbon deposits on the inside of the halogen light bulbs, caused by the burning of the tungsten filament, and re-deposits it back on to the filament, resulting in a light bulb which can be burned at a higher temperature therefore creating, both a whiter as well as a brighter light per watt than a regular bulb.

Figure 2: Halogen bulb

Halogen light bulbs come in many shapes and sizes, some directional others not, some quite small others the size of regular bulbs, some fit into normal sockets other require special sockets and voltages to work. Possible uses may include jobs where color is important because of its excellent color rendering of its whiter light, or it's physically smaller size has led to a lot of unique of designs of lamps and fixtures that would not have been possible with the size of regular bulbs. The smaller size of the bulb has also lead to better designs of reflectors, increasing the efficiency of halogen light bulbs as a directional light source for track lighting. (bulbsusa.com, Los Angeles, 2013)

3.3 High intensity discharge (HID) light bulbs

High intensity discharge or HID light bulbs are different from standard halogen bulbs in that HID lights replace the filament of the light bulb with a capsule of gas. High Intensity Discharge (HID) is lamps in which an arc passing between two electrodes in a pressurized tube causes various metallic additives to vaporize and release large amounts of light. The light in HID lights is emitted from the arc discharge between two electrodes. HID light bulbs require ballasts to operate, which supply proper voltage and control current. The amount of light produced by HID light bulbs is greater than any standard halogen bulbs, and HID light bulbs also consume less energy and last longer than those regular halogen bulbs.

Three most popular types of HID light bulbs on the market are: Mercury Vapor, Metal Halide, and High Pressure Sodium.

3.3.1 Mercury vapor lamps

Mercury vapor lamps belong to the traditional type of high-intensity discharge lighting, and they are primarily used for street lighting.

Figure 3: Mercury vapor lamp

Mercury vapor lamps can produce 50 lumens per watt approximately. They cast a very cool blue/green white light. Most of the indoor mercury vapor lamps in arenas and gymnasiums have been replaced by metal halide lamps which have a higher color rendition index and a higher efficacy. However, like high-pressure sodium lamps, mercury vapor lamps have longer life hours (16,000-24,000 hours) than the metal halide lamps. (bulbsusa.com, Los Angeles, 2013)

3.4 Compact fluorescent bulb

The Compact Fluorescent Light Bulbs belong to a type of fluorescent bulbs only it is in compact form that has different shapes and sizes which are mostly designed to replace your regular incandescent light bulbs.

Fluorescent light bulbs (including compact fluorescents) are more energy-efficient than regular bulbs because of the different method they use to produce light. Regular bulbs (also known as incandescent bulbs) create light by heating a filament inside the bulb; the heat makes the filament white-hot, producing the light that you see.

Figure 4: CFL bulbs

A lot of the energy used to create the heat that lights an incandescent bulb is wasted. A fluorescent bulb, on the other hand, contains a gas that produces invisible ultraviolet light (UV) when the gas is excited by electricity. The UV light hits the white coating inside the fluorescent bulb and the coating changes it into light you can see. Because fluorescent bulbs don't use heat to create light, they are far more energy-efficient than regular incandescent bulbs.

3.4.1 Advantages

Efficient: Compact Fluorescent Light Bulbs are four times more efficient and last up to 10 times longer than incandescent. A 22 watt compact fluorescent light bulb has about the same light output as a 100 watt incandescent. Compact fluorescent light bulbs use 50 - 80% less energy than incandescent.

Less Expensive: Although compact fluorescent light bulbs are initially more expensive, you save money in the long run because compact fluorescent light bulbs use 1/3 the electricity and last up to 10 times as long as incandescent.

Pollution control: Replacing incandescent bulbs with compact fluorescent light bulbs will keep a half-ton of CO_2 out of the atmosphere over the life of the bulb.

High-Quality Light: Newer compact fluorescent light bulbs give a warm, inviting light instead of the "cool white" light of older fluorescents. They use rare earth phosphors for excellent color and warmth. New electronically ballasted compact fluorescent light bulbs don't flicker or hum.

Versatile: Compact fluorescent light bulbs can be applied nearly anywhere that incandescent lights are used. Energy-efficient compact fluorescent light bulbs can be used in recessed fixtures, table lamps, track lighting, ceiling fixtures and porch lights. 3-way compact fluorescent light bulbs are also now available for lamps with 3-way settings. Dimmable compact fluorescent light bulbs are also available for lights using a dimmer switch.

3.4.2 Disadvantages

The main disadvantage of the CFLs is their mercury content. CFLs contain small amounts of mercury which is a toxic metal. This metal may be released if the bulb is broken, or during disposal. For more information about mercury and CFLs, see below. Mercury is a toxic metal associated with contamination of water, fish, and food supplies, and can lead to adverse health effects. A CFL bulb generally contains an average of 5 mg of mercury. (bulbsusa.com, Los Angeles, 2013)

3.5 Light emitting diode (LED)

LEDs (Light Emitting Diodes) are solid light bulbs which are extremely energy-efficient. When first developed, LEDs were limited to single-bulb use in applications such as instrument panels, electronics, pen lights and, more recently, strings of indoor and outdoor Christmas lights.

Figure 5: LED bulb

Manufacturers have expanded the application of LEDs by "clustering" the small bulbs. The first clustered bulbs were used for battery powered items such as flashlights and headlamps. Today, LED bulbs are made using as many as 180 bulbs per cluster, and encased in diffuser lenses which spread the light in wider beams. Now available with standard bases which fit common household light fixtures, LEDs are the next generation in home lighting.

A significant feature of LEDs is that the light is directional, as opposed to incandescent bulbs which spread the light more spherically. This is an advantage with recessed lighting or under-cabinet lighting, but it is a disadvantage for table lamps. New LED bulb designs address the directional limitation by using diffuser lenses and reflectors to disperse the light more like an incandescent bulb.

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness.

3.5.1 Advantages

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

Durable: Since LED light bulbs do not have a filament, they are not damaged under circumstances when a regular incandescent bulb would be broken. Because they are solid, LED bulbs hold up well to jarring and bumping.

Cool: These bulbs do not cause heat build-up; LEDs produce 3.4 btu/hour, compared to 85 for incandescent bulb. This also cuts down on air conditioning costs in the home.

Mercury-free: No mercury is used in the manufacturing of LEDs.

More efficient: LED light bulbs use only 2-10 watts of electricity (1/3rd to 1/30th of Incandescent or CFL) Small LED flashlight bulbs will extend battery life 10 to 15 times longer than with incandescent bulbs. Also, because these bulbs last for years, energy is saved in maintenance and replacement costs. For example, many cities in the US are replacing their incandescent traffic lights with LED arrays because the electricity costs can be reduced by 80% or more.

The following table shows the comparison of various lighting devices in different aspects.

Table 1: Comparison of various lightening devices

	LED	Incandescent	CFL
Life span(average)	50,000 hrs.	1,200 hrs.	8,000 hrs.
Watts of electricity used (equivalent to 60 watt bulb)	6-8 watts	60 watts	13-15 watts
Price	Rs. 500 (4 watt)	Rs. 25 (100 watt)	Rs. 350 (15 watt)
Mercury content	no	no	yes
Sensitivity to low temp.	no	some	yes (below 10^0F
Sensitivity to humidity	no	some	yes
Heat emitted	3.4 btu/hr	85 btu/hr	30 btu/hr
Durability	Very durable	Not very durable	Not very durable

(Nu-Way Systems and Design Recycle Inc, 2010)

Cost-effective: Although LEDs are expensive, the cost is recouped over time and in battery savings. For the

AC bulbs and large cluster arrays, the best value comes from commercial use where maintenance and replacement costs are expensive.

Light for remote areas: 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 (bulbsusa.com, Los Angeles, 2013).

4. Sample size calculation

The table below shows the number of households using various sources for their lighting purpose in the three districts of the Kathmandu valley.

Table 2: Sources of lighting in the Kathmandu valley

Area	Kathmandu	Bhaktapur	Lalitpur
Total households	435544	68557	109505
Electricity	427363	67037	105766
kerosene	2330	670	1906
Bio-gas	1815	251	338
Solar	200	49	231
Others	407	113	172
Not stated	3429	437	1092

(Center Bureau of Statistics, 2011)

Since our research intends to find the potential electricity savings from the use of LED bulbs for lighting purpose in the Kathmandu valley, the population size for this report is only the sum of the households of the three districts who use electricity as the source for lighting.

The total households who use electricity for lighting purpose in the Kathmandu Valley are 600166 which is our population size. And the sample size is 101.

The sample size for this survey was calculated using the software called sample size calculator.

The confidence interval also called margin of error is the plus-or-minus figure on the main answer. In this survey our confidence interval is 9.75 which mean our finding will be deviated by 9.75 plus-or-minuses.

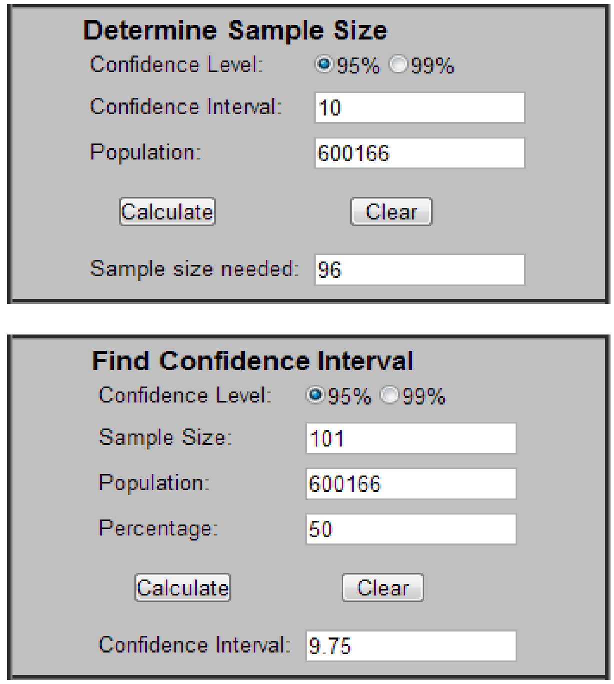

Figure 6: Sample size and confidence interval calculation

(Creative Research Systems, 2012)

The confidence level tells us how sure we can be. It is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means we can be 95% certain; the 99% confidence level means we can be 99% certain. Most researchers use the 95% confidence level. This survey has also used 95% confidence interval.

5. Survey findings

5.1 Participants of the survey

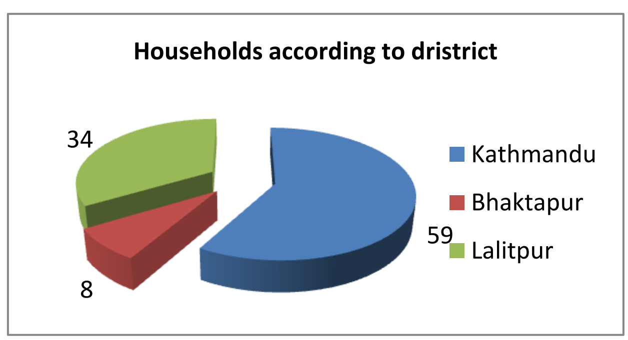

Figure 7: Distribution of household samples by districts

The survey was carried out among the people who live with their families in the Kathmandu valley. Of the total 101 participants, 59 households were from Kathmandu district, 34 were from Lalitpur and 8 were from Bhaktapur.

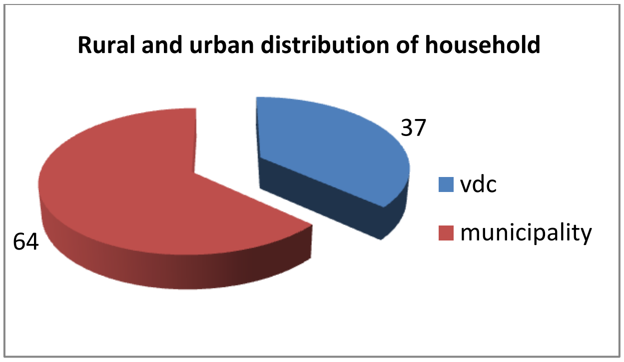

Figure 8: Distribution of household samples by rural and urban areas

64 participants were from municipalities of the three districts whereas 37 were from the VDCs.

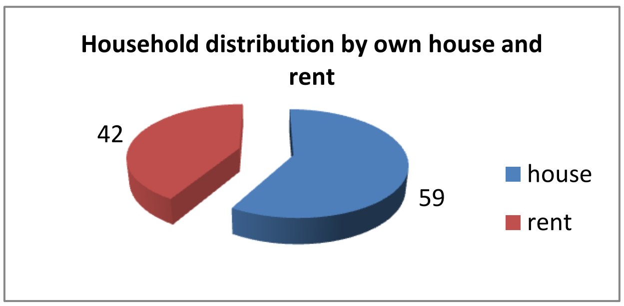

Figure 9: Distribution of household samples by own house and rent

Of the total 101 participants, 59 had their own houses whereas 42 households live on rent.

5.2 *Preference to lighting source*

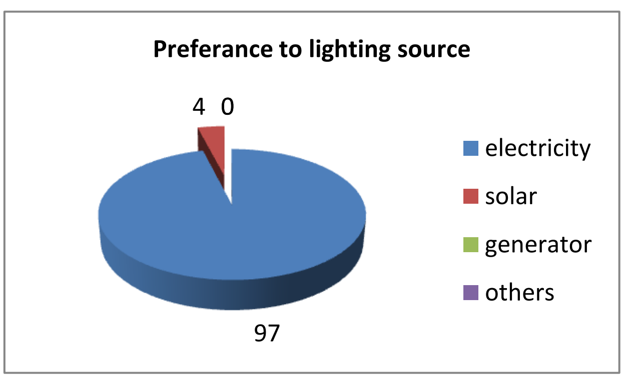

Figure 10: Preference to lighting source

The households which have main grid electricity as energy source were considered for the survey. And among the 101 participants, 97 considered electricity as the best source of energy whereas 4 participants considered solar as the best source of energy. No on considered generator and other sources for energy supply. From this we can conclude that grid line electricity is the most preferred option for household energy supply in the Kathmandu valley despite of load shedding. The reason might be of cheaper price of energy from electricity than from other sources. Only 4 participants liked solar, the reason might be intermittency and large initial investment.

5.3 *Preference of lighting devices*

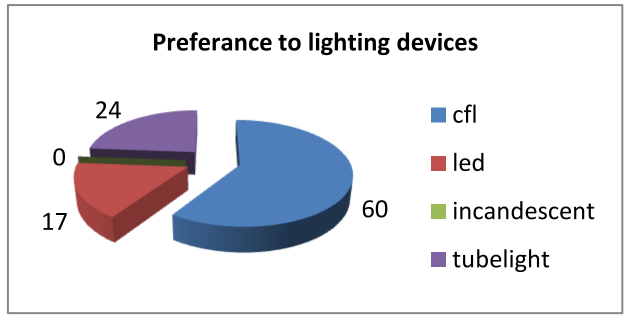

Figure 11: Preference of lighting devices

Even though LED bulbs are the most efficient lighting devices, majority participants chose CFL bulbs as the most desired lighting device in their rooms. CFL lights were followed by the tube lights or the fluorescent tubes. LED came in third. And no one chose incandescent bulbs.

There is some awareness among the people about the energy efficiency. This is the main reason for incandescent bulbs to be the least preferable as they are least efficient. But people are not aware enough to rank LED above CFL and tube light. So, some awareness work must be done to increase energy efficiency in lighting purpose in the Kathmandu valley.

5.4 *Factors affecting the selection of the lighting devices*

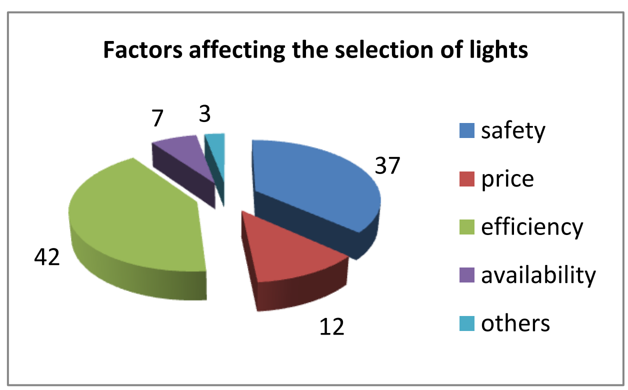

Figure 12: Factors affecting the selection of the lighting devices

42 individual chose efficiency as the main reason behind choosing the bulbs, 37 choose safety, 12 chose price while only 7 chose availability.

So, price of the bulbs is not the factor affecting much on the selection of the bulb but efficiency and the safety are. CFL are efficient but not enough efficient as the LED and CFL also has the health hazard due to the presence of the mercury. But, the majority of the participants ranked CFL in the first. It concludes that even though people are interested in the efficiency and the safety, due to lack of information about the LED bulbs, they are still relying on the old technology.

5.5 *Pattern of the lighting devices used in the households*

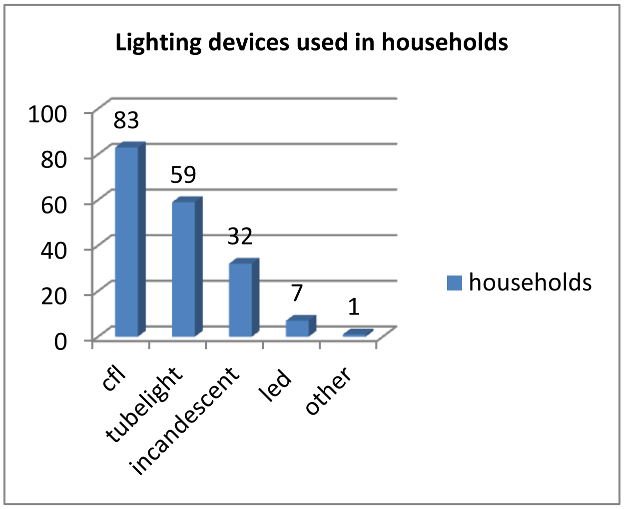

Figure 13: Pattern of the lighting devices used in the households

Besides the CFLs, tube lights, incandescent and LEDs, the use of other types of lighting devices in the households in negligible. Even though from the above pie charts, it is known that the popularity of LED is third besides the CFLs and the tube lights, but in reality, the use of LED is behind the incandescent bulbs. Only 7 households out of 101 currently use LED.

Therefore we can conclude that a considerable amount of energy can be saved by switching from the old technology devices to the latest lighting devices.

5.6 *Replacements of the bulbs by the LED bulbs*

Table 3: Wattage of various bulbs according to the lumen

lumen	incandescent	CFL	LED
2600 lm	150 w	32-35 w	25-28 w
1600 lm	100 w	23-26 w	16-20 w
1100 lm	75 w	18-22 w	+13 w
800 lm	60 w	13-15 w	8-12.5 w
450 lm	40 w	9-11 w	6-9 w

(2013 eBulb, Inc)

The above table shows the equivalence of various bulbs for generating similar light energy in terms of lumen. In this report, we tried to calculate the tentative amount of energy that can be saved if we switch all other lighting devices by the LED bulbs. With the help of the above table we mathematically replaced all the lighting devices with the LED bulbs. While doing so, the different wattage of the LED bulbs available in the local market was also considered.

Table 4: Power rating of various types of tube lights

Variant	Power Rating	Ballast Type available	Power Rating with Ballast
T-12	40 Watts	Electromagnetic (15 Watts) Electronic (3 Watts)	55 W (electromagnetic) 43 W (electronic)
T-8	36 Watts	Electromagnetic (15 Watts) Electronic (3 Watts)	51W (electromagnetic) 39 W (electronic)
T-5	25 Watts (for 4 ft. long tube) 13 Watts (for 2 ft. long tube)	Electronic (3 Watts and 1watt for 4ft and 2ft tubes respectively)	28 W (for 4 ft. long tube) 14 W (for 2 ft. long tube)

(www.bijulibachao.com, 2012-2013)

The above table lists the various types of tube lights available in the market. In fact, tube lights are also fluorescent lights but are in the form of rod instead of bulbs and have higher wattage thus making it more suitable for large rooms and spaces. They have ballast and while rating power, the wattage of the ballast should also be considered besides that of the tube light itself. For example, a 40 watt tube light actually consumes either 43 watt or 55 watt according to the ballast type used. In this report, it is assumed that the ballast type used in the lights is electromagnetic as electronic ballasts are the new technology and the survey is done on the already installed houses.

The survey was done among 101 households. The total number of households in the Kathmandu valley that depend on the grid electricity for the lighting purpose is 600166 which is our population size. By using the unitary method, the amount of energy consumed for the lighting purpose in the valley was calculated from the data collected from 101 households.

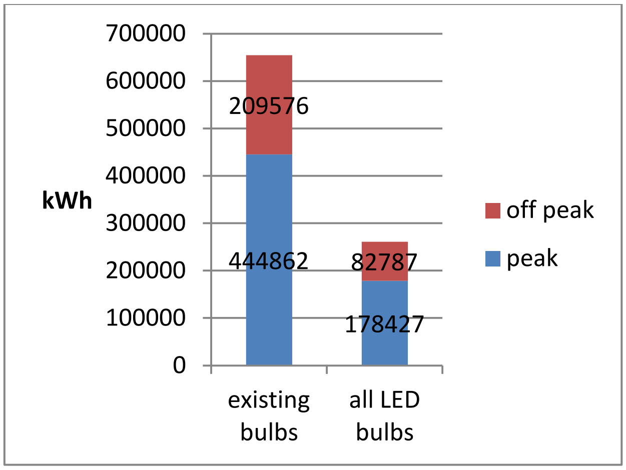

Figure 14: Daily energy consumption for lighting

From the above chart, we can see that up to 60% of the energy can be saved if we replaced all the other lighting devices in the Kathmandu valley with the LED bulbs. The current electricity tariff is Rs. 7.30 for consumption of energy from 21-250 units. (Nepal Electricity Authority, 2070). Thus in monetary term, Rs.28, 70, 539 can be saved each day.

5.7 Energy consumption pattern for the lightening purpose

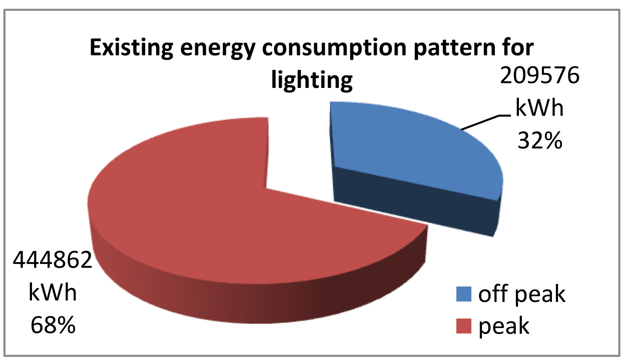

Figure 15: existing energy consumption patterns for lighting in peak and off peak period

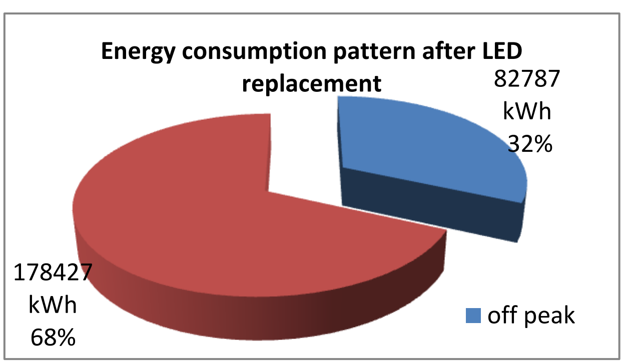

Figure 16: Energy consumption pattern for lighting in peak and off peak period after replacement of all bulbs by the LEDs

From the above chart, it is known that 32% of the energy is consumed for lighting purpose in the off peak hour whereas 68% of the energy is consumed in the peak hour for lighting. This is the case prior to the replacement of the bulbs by the LED bulbs. Here, the peak hour means 7-10 a.m. and 7-10 p.m. The case is similar if all the bulbs are replaced by the LED bulbs.

6. Conclusion

This study shows that the people in the valley are not much aware about the energy efficient lighting devices. CFL bulbs are quiet popular but the more advanced LED bulbs are not much popular. No one ranked incandescent lamps in the first priority among the lighting devices but in actual practice, quiet a considerable household still used them mean even though people are conscious about energy efficiency, they actually haven't done much to replace the inefficient devices. About 32 % of the energy is used for lighting in the off-peak period whereas rest 68 % is used during peak hours. About 654000 units (kW hour) of energy is used for the lighting purpose every day in the Kathmandu valley. And about 60% of that energy (i.e. about 393000 units) can be saved daily if we switched all the lighting devices to LED bulbs which mean around 2.8 million Nepali Rupees each day. At household level, the electricity consumption for lighting purpose will reduce from 423 kWh to 164 KWh annually saving around Rs. 2000. Besides saving money, this will also reduce the load shedding problem occurring in our country.

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