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# The Economic Feasibility Study of Light Emitting Diode (LED) Lamp Replacement for Rural Kerosene Lamps (Dhibari)

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**Abstract:** ***A million of people in India depend on kerosene based lamps, Dhibari, Lantern and candles for the purpose of lighting, because of non existence of electric network in harsh terrains and unreliable electricity supply. Due to this, they have spent a major part of their expenditure on lighting. In this paper a Light Emitting Diode (LED) Lamp is introduced with two modes of illumination, high and low. A illumination intensity of 7 lux and 0.64 lux of light output can be achieved by this LED lamp at 1 meter distance in high and low mode of illumination respectively. The LED lamp saves one third of expenditure on lighting as compared to Dhibari and Lantern.***

**Keywords:** Kerosene lamp, LED lamp, Unreliable electricity supply, Illumination intensity**.**

## 1. Introduction

"The current price of kerosene is around Rs 44.50 a litre, it is being sold in the range of Rs 13-14 a litre. The differential amount between the market price and the subsidized rate is directly transferred to the beneficiaries account."(The Hindu. Business Line, 8 April 2011 New Delhi) [1].

In India, a rural household acquires 10% of its Monthly Per Capita Expenditure (MPCE) on fuel and lighting. Due to dependence of 84% of rural household on firewood, agriculture residues and dung cake for cooking that probably are collected free of cost, the major part of expenditure is likely to be on lighting [2]. About 350 million people (in 74 million households) in India, who have no access of electricity, use kerosene for lighting. But due to intermittent and unreliable electricity supply, the millions of others who can access electricity also use kerosene for lighting in both rural and urban areas [3]. An analysis highlights the problems related *w*ith the kerosene distribution system after examining the subsidy based supply driven approach to distribution in terms of facilitating access to the poor[4]. The problems that observed are the differences in climatic conditions, lifestyles, economy and distance for remote villages. Many villages in India have no electric network extensions due to harsh terrain and geographical remoteness. In India, the subsidies of kerosene and liquid gas propane are as large as those for education [5]. The wholesaler and retailer commission rates increases with kerosene rates.

With the advent of solid state lighting using Light Emitting Diodes (LEDs), the dependence on kerosene lamps has considerably reduced for users. The off-grid LED lighting provides long term value benefits for the poor in developing countries [6]. Human health and particularly potential harmful risks for the eye due to smoke from kerosene lamp is a strong reason for the adoption of LEDs for lighting [7]. It can also prevent loss of the thousands of lives due to fires every year caused due to fuel base lighting [8]. A low energy requirement is the key point to make white LED luminary suitable for villages as compared to conventional incandescent lamp [9]. Due to improved spectral and energetic characteristics of white Light Emitting Diode (WLED) as compared to other domestic light sources all the traditional incandescent light sources are likely to be replaced by LED based sources by 2016 [7]. Rural Integrated Development services-Nepal uses White LEDs with solar photovoltaic (PV) systems and pico hydro power plants to implement lighting in villages as part of long term community development projects [9]. LED based lighting using PV is also promoted by Light up the World (LUTW) foundation in Asia including Nepal, India and Sri Lanka in their projects. In India, 1500 villages will be covered by LUTW over the next several years [8, 10]. For reducing the mining hazards, a low power and light weight LED cap lamp is becoming common to enhance safety [11].

A poor household in India normally use kerosene wick lamp called 'Dhibari' or candles for lighting purpose. In this paper an economical aspects of dhibari and different sized candles is analyzed and then it is compared with a Light Emitting Diode (LED) based lamp. This lanclanche battery operated LED lamp have no drawbacks that are normally associated with LED lamp with PV like maintenance of PV panels, high initial cost, checking the battery status etc. The Chaurey and Kandpal [2] discussed the ownership and fee-for-service/rental models of solar lanterns for CFL and LED based designs in India. It is based on centralized solar charging station concept. It is described that rural households having MPCE of Rs. 235-270 may be the users of solar lantern if available on rent with some limitations like limited hours of usage and responsibility of user for delivering the lantern to the charging station for recharging. Regions that have no adequate solar radiation will not be able to use solar lanterns. The simply designed LED lamp discussed in this paper can be used by the rural households having MPCE of Rs. 235-270 or less.

In this study GaAlN ultraviolet LED (double heterojunction) with suitable phosphor coating is used for LED lamp that emits warm white light spectrum. Such LEDs are cost effective and easily available in Indian market. It also meets our requirements such as color spectrum which is comfortable for human vision, easy maintenance, good energy efficiency and high portability . It will provide minimum required light intensity for movement around the living area.

## 2. Economical Aspect of Dhibari and Candles

The cost analysis of Dhibari, different sized candles and LED lamp is done to compare the costs per lumen hours of light for each device. The annual cost is the combination of initial cost and running cost of the lighting installation. The initial cost is almost zero in the case of dhibari and the running cost involved is the amount spent on kerosene consumption. The measured consumption rate of kerosene for dhibari with burning time is shown in Figure 2. It is based on the experiment performed by the author in the laboratory.

**Figure 1:** Dhibari and Candle

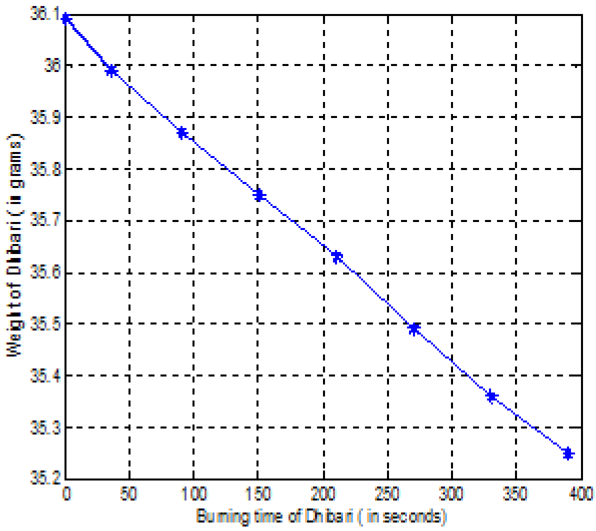



**Figure 2:** Rate of kerosene fuel consumption by Dhibari

The calculation based on this graph shows the 7.75 gram kerosene consumption per hour in dhibari, which is around 11.8 milliliters (ml) per hour by taking 0.67 as density of kerosene. Considering the use of dhibari 5 hours per day, the total consumption per day is

11.8 ml / hours x 5 hours / day = 59 ml per day.
59 ml /day x 365 days / year = 21.5 liters per year.

By taking Rs. 14 per liter as subsidy cost of kerosene in India in the year 2012 [1], total annual running cost of dhibari will be Rs. 301 per year or 16.5 paise per hour. It gives around 1/3 candle power light. With open market price Rs. 44.50 per liter of kerosene in India in the same year [1], the total annual running cost of dhibari will be amounts to Rs. 957 per year. Different sized candles of diameter 18.07 mm, 13.74 mm, 9.6 mm and 8.8 mm are analyzed for cost analysis. Their variation of weight with respect to burning time is shown in Figure 3.

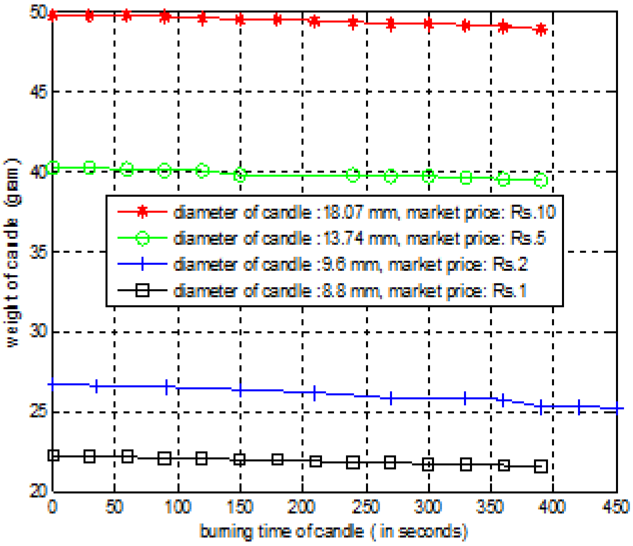



**Figure 3:** Rate of consumption of candles with respect to burning time

The calculated cost are Rs. 1.7 per hour, Rs. 1.6 per hour, Rs. 2.57 per hour and Rs. 1.3 per hour respectively for the candles of diameter 18.07 mm, 13.74 mm, 9.6 mm and 8.8 mm. These measured costs of illumination per hour for candles are much higher than the dhibari.

**Table 1:** Experimental result for output light intensity in front direction at 1 meter distance from light source

| *Light source* | *Output light ( in lux) at 1meter distance* |
|---|---|
| Dhibari | 0.642 |
| Candle ( Diameter=18.07 mm) | 0.320 |
| Candle ( Diameter=13.74 mm) | 0.830 |
| Candle ( Diameter=9.6 mm) | 0.820 |
| Candle ( Diameter=8.8 mm) | 0.430 |

## 3. Technical and Economical Aspect of LED Lamp

The design of LED based lamp is very simple. The LED lamp consists of twelve parallel connected white LEDs (double chip) of 5mm size with 47E resistance connected in series for low mode and 1E resistance for high mode as shown in Figure 4(b). It uses two 1.5 volt D sized lanclanche cells (unregulated).

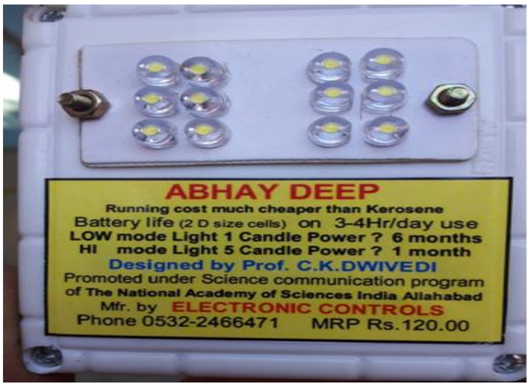



**Figure 4(a):** LED Lamp Module

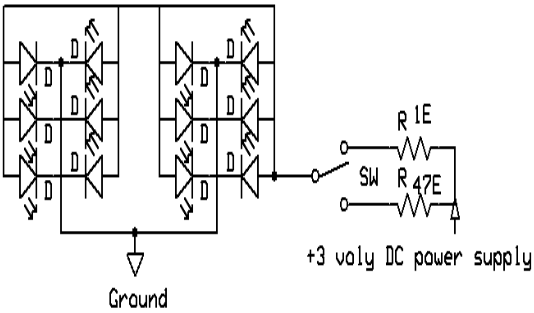



**Figure 4(b):** Circuit diagram of LED lamp


**Figure 5:** Two modes of illumination of LED lamp

A open circuit voltage of a fresh laclanche cell is typically 1.5 volts. As approximately 3 volts are necessary for LED lighting (actual voltage Vf (Forward Voltage Drop) across white LED is 2.6 to 2.75 volts at normal room temperature with an equivalent series resistor of 10 to 15 ohms), two serially connected laclanche batteries has been used within LED lamp. The proposed LED lamp can be operated in two modes of illuminating intensities. One is high mode of illumination giving light equal to a kerosene lantern and the other is low mode of illumination giving light equal to kerosene dhibari. The amount of current flow will become less in low mode of illumination so the intensity will also become low as compared to high mode of illumination. The user can select any one of the mode of illumination by simple slider switch. The middle position of the switch will be selected by the user to just switch off the LED lamp. The measured variation of output light intensity by change of direction from axis for both mode of illumination of LED lamp at horizontal distance of 8 cm from the LED lamp in laboratory's dark room is shown in Figure 6. This characteristic is commonly known as radiation pattern. The respective dashed lines shown in radiation pattern imply the amount of output light intensity of LED lamp from origin .Within 60 degree aperture angle, the intensity of LED lamp is around 1155 lux at 8 cm distance which is equivalent to 7 lux at 1 meter distance in high mode of illumination. In low mode of illumination, the intensity is around 100 lux at 8 cm distance which is equivalent to 0.64 lux at 1 meter distance. For illuminating the total floor area with appreciable light intensity, the LED lamp may be hanged from the roof at the same height from floor as the width of roof. For example, a 8 foot by 8 foot room will require hanging of LED lamp at 7 to 8 feet height to lit the total floor area of the room.

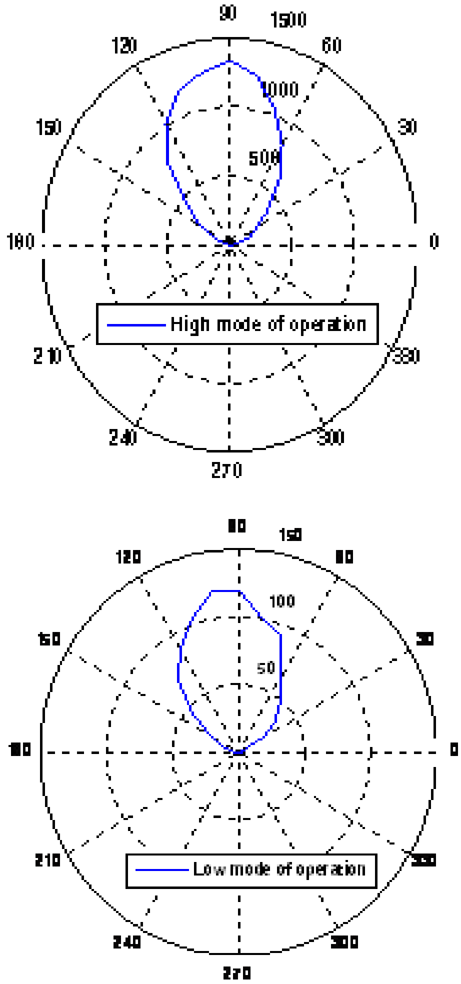



**Figure 6:** Radiation pattern of output light intensity of LED lamp

The initial value of current is around 70 mA and 9 mA respectively for high and low mode but it drops to 48 mA and 8 mA within few hours of operation and then the drop in current is almost exponential with used hours as shown in Figure 7. As mentioned earlier the total cost includes the initial cost and maintenance cost. Here the maintenance cost is the cost of batteries that will be replaced by the new batteries after discharging of the batteries to such level that final intensity drops to about one third of the initial intensity of LED lamp. This cost will be approximately Rs. 20 to 30 for two D sized batteries as the market price of each cell is between Rs. 10 to 15 depending upon the type of cell and manufacturer. Various types of laclanche D sized batteries are easily available in the market, including Panasonic, Nippo, Eveready and Geep.

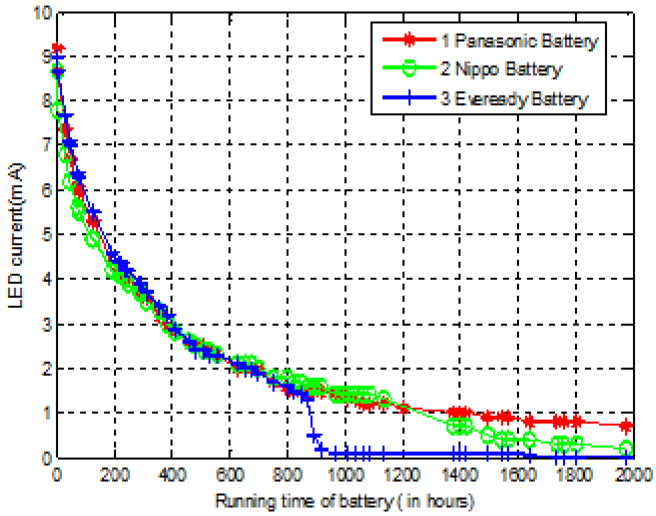



**Figure 7(a):** LED lamp in low mode of illumination

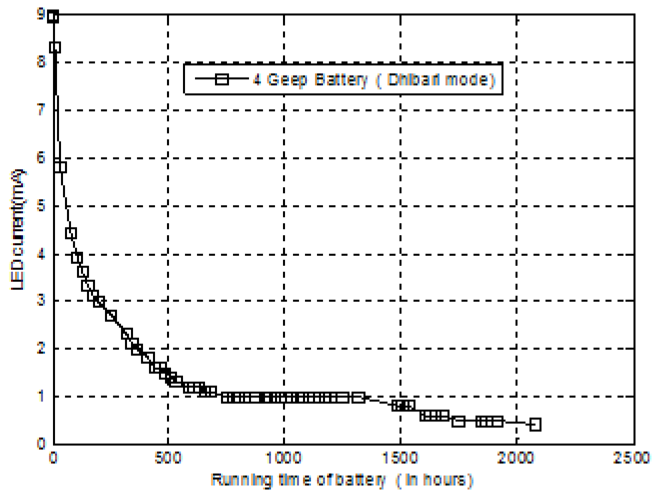
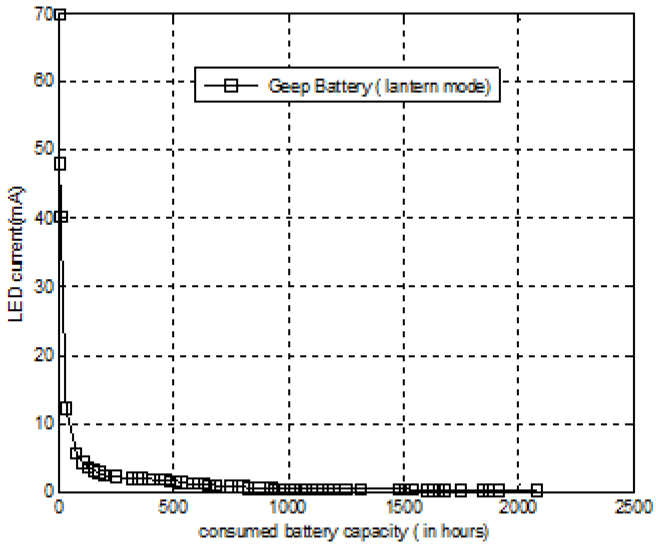



**Figure 7(b):** LED Lamp in low mode of illumination for Geep Battery



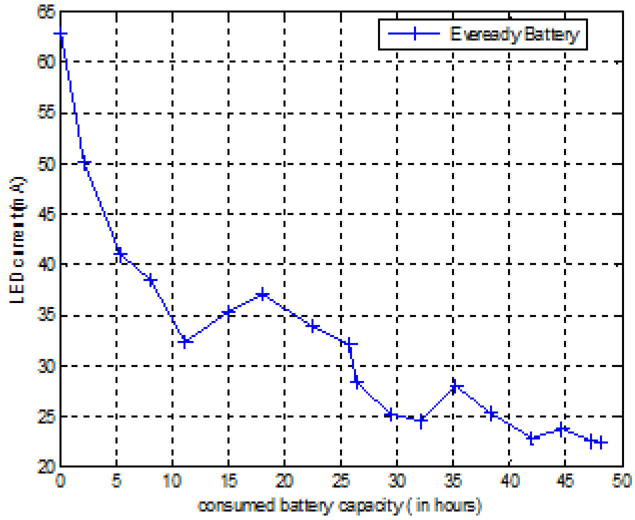




**Figure 7 (c):** LED Lamp in high mode of illumination for Geep and Eveready battery

**Figure 7:** Variation in LED current with running hours of battery supplied from local manufacturer

The graphs shown in Figure 8 illustrates the battery (under test) capacity consumed in units of milli ampere hours ( mAH) to show their relative characteristics of discharge with LED lamp in low mode ( Dhibari) and high mode ( Lantern) of illumination respectively. For 1, 2 and 3 type of cells as shown in Figure 8(a), we get around 2000 mAH life for intensity dropping to 1/3rd of starting intensity. At this intensity the light output will be around 1/3rd lux which is equal to Dhibari light. These curves were obtained on continuous operation. In intermittent use say 3 to 4 hours a day we expect 3000 to 4000 mAH discharge life as per manufacturer's information in their data sheets [12].

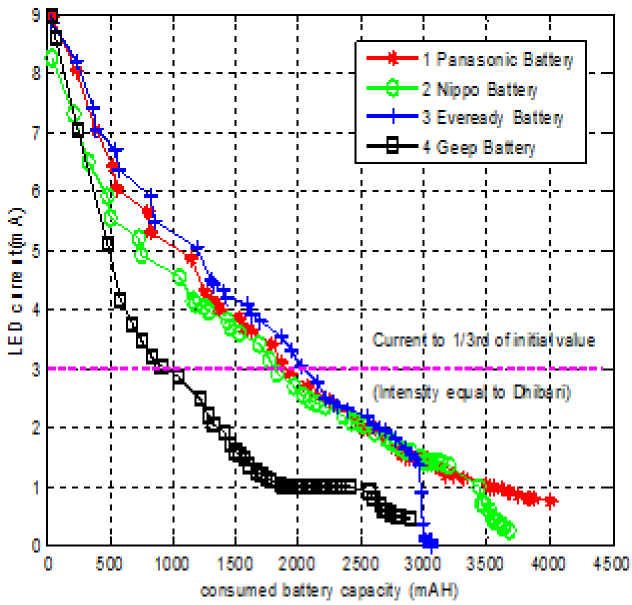



**Figure 8(a):** LED lamp in low mode of illumination

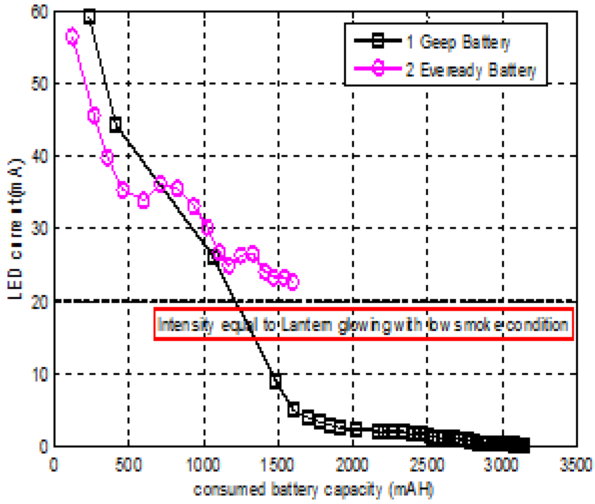



**Figure 8(b):** LED lamp in high mode of illumination

**Figure 8:** Discharge curves of low cost battery supplied from local manufacturer with respect to LED current (a) Panasonic, Nippo, Eveready and Geep batteries used in low mode of illumination of LED lamp (b) Geep and Eveready battery used in high mode of illumination of LED lamp.

Starting with one candle power of intensity of LED lamp, which requires 8-9 mA of current from the battery as per the observation shown in the curves of Figure 8(a), the light output intensity will become around 1/3rd candle power in about 633.33 hours for Panasonic battery at low mode of illumination of LED lamp. By considering the market cost as Rs. 25 for two cells of Panasonic, the running cost will be 3.9 paise per hour. We can take this point as almost end of life of battery for replacement (however the lamp may continue its service for next 200-300 hours with poor intensity). Considering the use of LED lamp 5 hours per day, the running period will be 127 days or approximately 4 months for Panasonic battery. Based on the above fact, the running cost of LED lamp will be equal to cost of 3 sets of battery (around Rs. 75) per year. Similar observations have been done for same D sized laclanche type batteries available from different manufacturers like Nippo, Eveready and Geep. The performance result of batteries for LED lamp is shown in Table 2. As about 5 to 15 lux of illuminance level is sufficient for normal day to day working of human being besides reading [8] so user can use LED lamp up to marked discharging point of batteries in the curve shown in Figure 8.

**Table 2:** Performance result of D sized Laclanche batteries used in LED lamp

| *Name of manufacturer* | *Mode of illumination of LED lamp* | *Market cost of two batteries ( one set)* | *Running hours for LED light upto 1/3rd of initial intensity ( equal to Dhibari intensity)* | *Running cost of LED lamp per hour for useful period of lighting* | *Running days of LED lamp for one set of battery at 5 hours per day* | *Number of sets required for LED lamp per year* | *Annual running cost of LED lamp* |
|---|---|---|---|---|---|---|---|
| Panasonic | Low | Rs. 25 | 633.33 hours | 3.9 paise per hour | 127(4.2 months) | 3 | Rs. 75 |
| Nippo | Low | Rs. 25 | 600 hours | 4.2 paise per hour | 120(4 months) | 3 | Rs. 75 |
| Eveready | Low | Rs. 25.5 | 666.67 hours | 3.8 paise per hour | 133(4.4 months) | 3 | Rs. 76.5 |
| Eveready | High | Rs. 25.5 | 90 hours | 28.3 paise per hour | 18 | 20 | Rs. 510 |
| Geep | Low | Rs 22 | 333.33 hours | 6.6 paise per hour | 67(2 months) | 6 | Rs. 132 |
| Geep | High | Rs.22 | 65 hours | 33.8 paise per hour | 13 | 28 | Rs. 616 |

**Table 3:** Comparative cost analysis of Kerosene based Lamps (Dhibari and Lantern) with LED lamp

**Table 3 (a):**

| *Light source* | *Running cost* |
|---|---|
| Dhibari (Kerosene based Lamp) | 16.5 paise per hour at subsidized cost of Rs. 14 per litre of Kerosene |
| | 52.4 paise per hour at open market cost of Rs. 44.50 per litre of kerosene |
| LED Lamp (Low mode of illumination ) | 3.8 paise per hour at low mode of illumination 3.9 of LED lamp |

**Table 3 (b):**

| *Light source* | *Running cost* |
|---|---|
| Lantern (Kerosene based Lamp) | 112.7 paise per hour at open market cost of Rs. 44.50 per litre of kerosene [13] |
| LED Lamp (High mode of illumination) | 33.8 paise per hour at high mode of illumination |

The comparative cost analysis of Dhibari with LED lamp is shown in Table 3(a). It clearly shows that the running cost of LED lamp is one third of the running cost of dhibari. The data illustrated in the Table 3(a) for Dhibari (kerosene based lamp) has been discussed at page 2 for open market and subsidized rates of kerosene. The output light intensity of LED lamp decreases gradually with respect to running time so user has enough time for replacement of batteries before full discharging of battery.

The amount of kerosene that the beneficiary get at subsidized rate is not sufficient for family of 3 to 4 lanterns so they have to purchase kerosene at open market price. Thus the running cost of lantern becomes higher than the LED lamp operated at high mode of illumination. The rural households having MPCE of Rs. 235 – 270 or less who cannot afford the open market price of kerosene, forced to depend on the quantity of kerosene obtained at subsidized rate. Since Dhibari consume less kerosene as compared to lantern hence poor households use Dhibaries so that quantity of kerosene becomes sufficient for family. According to Table 3, the proposed LED lamp is cost effective than kerosene based lamps.

## 4. Conclusion

As the pricing in petroleum products become deregulated, the rural poor of developing countries find difficult to cope with this situation as kerosene based lamps are their primary choice for lighting. The proposed LED lamp is more users friendly and cost effective than kerosene based lamps with less maintenance and hazards. By replacing kerosene based lighting sources with LED based lamps, the improvement in living standards, health and education of rural people can be expected.. With the advancement in solid state technology, the LED lamps will be available with more light output using the same amount of energy.

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