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Comparison of Performance of Electric Lighting Systems for Rural Nepal

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1. Introduction

In many rural places in Nepal, the people are using kerosene, tree resin lamps or candles for night lighting. The main problem with these types of lighting system is the limited amount of light they produce. Resin lamps also produce large amounts of smoke, which produces respiratory and eye problems. Due to the dimness, it also causes eye strain for detailed or fine work. Study during the night is most difficult with these types of lighting.

Lighting by kerosene is not affordable in the remote areas as the transportation is difficult and expensive. The main alternative to these types of lighting schemes is lighting by electricity. Hydro power and solar power are usually the only alternatives for the generation of the electricity in rural Nepal. The advent of inexpensive and efficient compact fluorescent lighting (CFL) and white light emitting diodes (WLEDs) has opened the opportunity for very small scale power to have a significant impact on the lighting needs of the remote communities.

Recommended lighting levels are given in table 1.

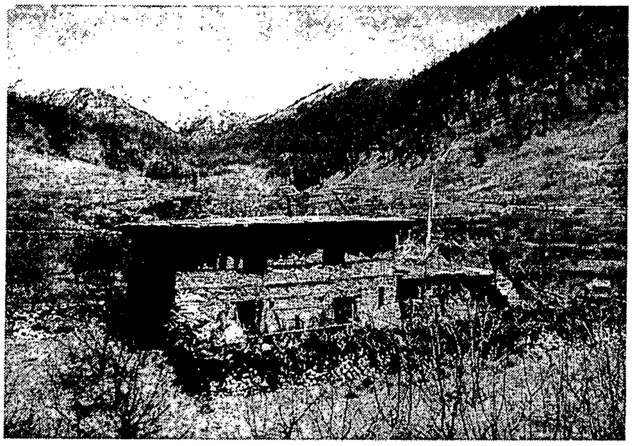

Fig. 1. Home powered by a photovoltaic panel for lighting in remote Nepal (Photo: Alex Zahnd 2003)

Table 1 Minimum light Required for Interior Use (adapted from [1])

Place	Description	Illumination (Lux)
Offices	General Office	300
	Conference Hall	300
	Entrance Hall	150
Houses	Kitchen	200
	Casual Reading	150
	Study Room	300
Shops	Store Room	200
	Other Areas	150-300
Assembly Shop	Fine Work	800
	Medium Work	300
	Rough Work	150
School	Classroom	150-500
	Drawing Hall	500-1000

2. Sources of Electrical Power

The sources of electrical power that are possible in remote areas of Nepal are mainly solar power and hydro power.

A hydro power which has a head of 2 metres and a flow rate of 30litre/sec can generate 200W of power, which may be sufficient to provide lighting to an entire village when using WLEDs and CFLs. Hydro power has the advantage that it does not need batteries for night use, unlike solar power from photovoltaic panels.

3. SOURCES OF LIGHT

There are mainly three sources of light currently in use: incandescent, compact fluorescent and white light emitting diode. Tube fluorescent bulbs are not usually used in remote areas of Nepal as the probability of the tubes breaking in transit is very high.

Fig. 2. 200W hydro power used for village electrification.

Fig. 3. 7W compact fluorescent lamp in house

Incandescent lamps use most of the electrical energy in heat rather than in light. About 90%[2] of the electrical energy is converted into heat energy and the remaining 10% only is converted into light. Their life time is much lower compared to the nominal CFL and WLED lifetimes. They have lumens/Watt figure of 15-24 lumens/Watt [2].

Compact fluorescent lamps are the compact form of the fluorescent tube. They are nominally found in 3, 7, 12, 18 and 20 Watt. They have nominally a lumens per Watt figure of 25-80 lumens/Watt [2], although experiece suggest that the usual figure is near 25lm/W. However, their output has been observed to be significantly affected by the bulb temperature and full light output does not arise until the sufficient tube temperature has been reached.

WLEDs are increasingly being in used these days. WLED lamps are often found in the rating of about 1 Watt. They consume little power and the life time of the WLEDs are high in comparison with the CFL. This is in part due to their electrical lifetime and also due to the robustness of the resin impregnated body.

The small physical size and epoxy resin construction of the WLEDs is more useful in transporting them to the rural areas of an underdeveloped country like Nepal, since they are most unlikely to be broken. They nominally have the lumens/Watt figure of 24 lumens/Watt [3]. Although the WLEDs have a nominal lifetime of 100,000 hours [4], the lamp driver circuit lifetime must also be considered.

4. Lamp Measurement

A black box was constructed for the comparison of the performance of the different lamps at short distances. The black box was constructed in such a way that no light can penetrate inside.

Measurement of the light output at distances of a metre or more was carried out on the moonless night on a grassy surface. Comparison of the light output inside the black box and the light output in a moonless night at same distance of 27 cm showed almost the same result, hence the test area was considered suitable.

5. Measured Lamp Output

The smallest commonly available CFL is rated at 3Watts, and so this is used to compare to the 1Watt WLED lamp.

The CFL does not have an omni directional light output. Its output varies significantly with direction as shown in figure 4. As the CFLs are often bayonet mounted on the ceiling, the light reaching the people below is often reduced.

When the CFL light output is compared to that of the WLED, the broadside of the CFL has been used as a comparison.

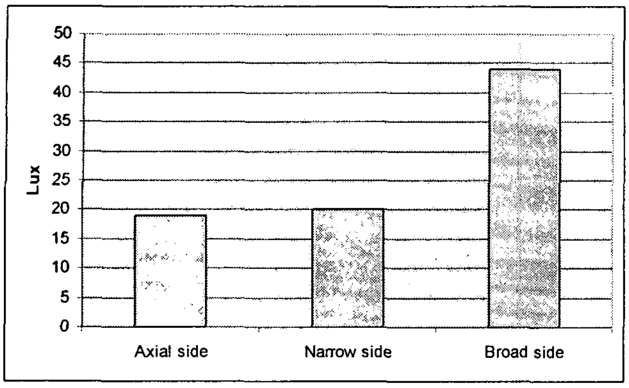

Fig. 4. Light output of CFL as a function of direction at 27cm distance.

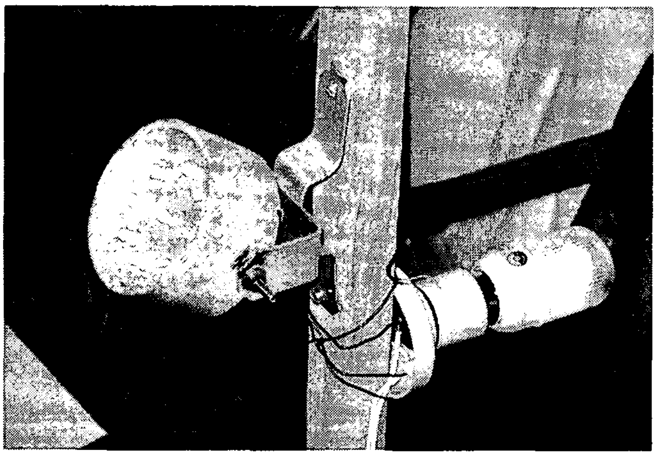

Fig. 5. 1W WLED lamp on left and 3W CFL on the right, as used in these tests.

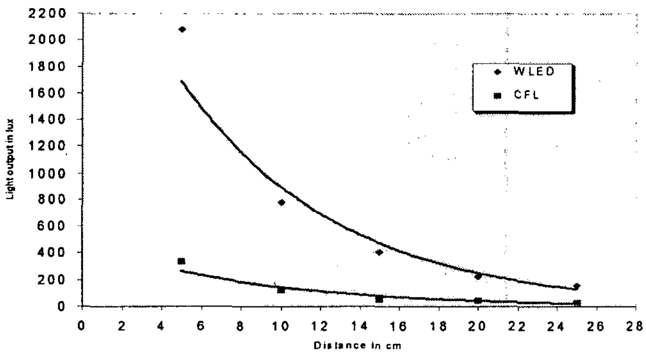

Fig. 6. CFL and WLED light output performance as a function of distance.

Figure 4 shows the two lamp light outputs at a close distance, extending up to the distance that might be appropriate for a desk or reading lamp. In both cases, the lamps are positioned in the usual vertical way, without any additional reflector. From table 1, it can be seen that the WLED lamp provides sufficient light for casual reading, but the 3W CFL does not.

At larger distances, the effect of using a aluminium reflector with the CFL is shown in comparison to the WLED lamp in figure 7. It shows that the use of a reflector is most beneficial for a CFL and that without a reflector, the lamp's performance is poor.

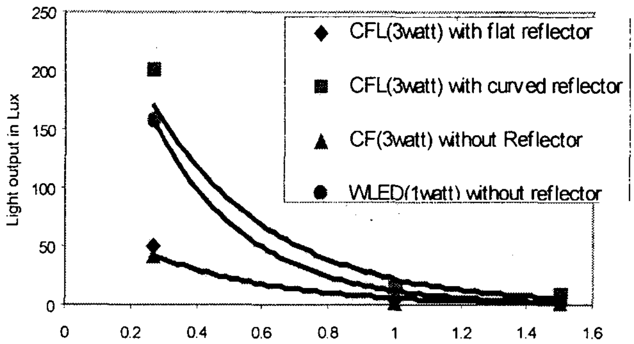

Fig. 7. Comparison of WLED with CFL with and without reflector at larger distances. (CFL is positioned broadside)

The benefit of a reflector on the CFL is clearly large, however, its performance is still not so much better than the WLED lamp, despite being of a nominal capacity of 3 times the power.

At distances of 1.5m and above, there are low levels of illumination, but experience has shown that it is still possible to read with the white LED lamp, but it is better used for general illumination.

6. Light Output Performance as a Function of Voltage Variation

In Nepal, there are often significant supply voltage variations from the supply. These variations can be experienced as causing an annoying light flickering, or even long term voltage reductions of the order of 40-50% can be experienced from the main grid. Hence, consideration must be given to the effect of a voltage change on the light output. For rural areas with independent power supplies, the voltage variations would not expected to be large, but should small scale industries start, then it would be expected to be a problem.

The CFL rated voltage is 220V and the WLED rated voltage is 12V and figure 8 shows the effect of a percentage change on these supply voltages. The CFL has an electronic ballast, and hence is able to compensate for the voltage variations well. In this WLED lamp, a simple series resistor is used to regulate the current, and hence it is particularly voltage sensitive. Consideration has been given to and electronic current regulator, but the presently, the lifetime would reduce too much and the cost would substantially increase.

Consequently, if there is to be significant voltage variations, a CFL is presently a better choice for a more constant light output.

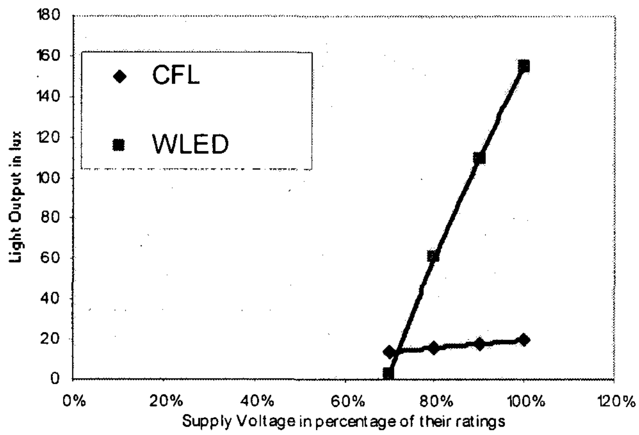

Fig. 8. Light output as a function of supply voltage. CFL has no reflector.

7. Lifetime and Cost

Life time and the cost of the lamp is also a major factor for the determination of the efficiency of the lamp. Lifetime of the three different types of lamps are compared below.

For the annual costs, a use of 4 hours per day is assumed.

Table 2 assumes electricity in which the infrastructure cost does not have to be considered. It is clear that the 1W WLED lamp is significantly cheaper in the long term due to its reduced energy consumption, but the comparison is more dramatic when the infrastructure cost is considered. By using very low electricity consumption lamps, the whole power system can be reduced – a smaller generator used, smaller wires and for a given generator size, many more houses can be connected to the system. If for example, a comparison is made between the use of 25W incandescent lamps and WLED lamps, 25 times the number of houses can be connected to the electricity system.

Table 2 Comparison of the lifetime and the cost of Incandescent, CFL and WLEDs Lamps of similar light output assuming grid supplied electricity. (US$1 = NRs76)

	25W Incandescent Lamp	**3W CFL**	**1W WLED Lamp**
Life time	2000 hours	10,000 hours[5]	100,000 hours[4]
Cost	30	70	600 (estimate)
Energy cost per year (NRs9/kWhr)	328	39	13
Total cost per year	350	49	22

8. Conclusion

The use of WLED lamps has been shown to be highly effective in comparison with CFLs. CFLs can be made similarly effective if they use a reflector and the bulb is suitably oriented. However, due to their increased electricity consumption and reduced lifetime, the WLED on an annual cost basis is much cheaper. The effect is increased if physical breakages are considered as CFLs are fragile and if the infrastructure costs is taken into account. The reduced power consumption of a WLED lamp is such that a much smaller infrastructure cost is possible, or many more houses can be connected to the local grid, thereby reducing the cost per house drastically.

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